System of Technical Control for Cane Sugar Factories in INDIA

Second Revised Edition 2005

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SYSTEM OF TECHNICAL CONTROL FOR CANE SUGAR FACTORIES IN INDIA

Revised in 1988 by
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Second revision in 2005

by

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"To the Technologists of the
Cane Sugar Industry in India"

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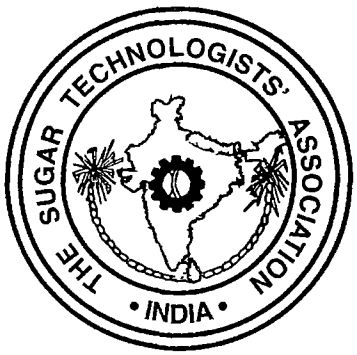

THE SUGAR TECHNOLOGISTS'
ASSOCIATION OF INDIA
NEW DELHI

The Association was started in 1925. It is an organisation of scientific workers & others directly interested in the technological advancements of the Sugar Industry. The Deccan Sugar Technologists' Association & The South Indian Sugarcane & Sugar Technologists' Association of India are its affiliated organisations. This Association is affiliated to I.S.S.C.T. The President of this Association is ex-officio Regional Vice-Chairman of I.S.S.C.T. & President of the National Committee of ICUMSA. Its affairs are run by a Council elected every two years by its own Members. The Council is assisted by Standing Committees on Research and Investigation, on Publications, on off season Employment, on Uniform System of Chemical Control and on Indian National Committee of ICUMSA.

The STAI is being represented in different Government bodies in their different committees viz. Bureau of Indian Standard's Sugar sub-Committee FAD-2.

The Association endeavours to serve the Sugar Industry. It solicits your co-operation in enabling the Association to fulfil the task.

FOREWORD

The Indian sugar industry has been growing year after year, currently there are 566 sugar factories in existence and more are under various stages of establishment. India has been world's largest producer of sugar, reaching a level of over 20 million tons in 2002-03 season.

The Sugar Technologists' Association of India (STAI) was founded in the year 1925, has been actively associated with the task of achieving uniformity in the methods of sampling, analysis and chemical control in the sugar factories. A hand book known as "Methods of Chemical Control" prepared by Mr. Noel Deerr (the then President of the STAI) was published by the Association in 1936. In 1954, the Development Council for Sugar Industry constituted by the Government of India under the Industries (Development and Regulation) Act, 1951, appointed an Expert Committee under the Chairmanship of Shri R.C. Srivastava (Ex-Director of the National Sugar Institute, Kanpur) which prepared a revised draft of the book. This draft was again revised by another Committee constituted in 1961 under the Chairmanship of Shri S.N. Gundu Rao (the then Director of the National Sugar Institute, Kanpur) and was published by the STAI in June, 1965.

During the years back followed, the process controls and analytical knowledge advanced, the expert committee appointed by the Govt. of India evolved a set of efficiency norms. Keeping the above objective in view, the STAI in 1986 entrusted the work of revising the book of Mr. N.C. Varma, who is a renowned sugar technologist, who took up this task and a revised version incorporating the norms of efficiency was published in 1988.

In the recent years, further new methods of analysis have been introduced by ICUMSA (International Commission for Uniform Methods of Sugar Analysis) and keeping these and other technological developments in view, the Association took up the task of revising and updating of the book. Prof. S.K. Gupta of NSI Kanpur was entrusted with the task and a revised version of the book is now being released.

On behalf of the Association, I would like to place on record my appreciation of the work done by Prof. S.K. Gupta and his associates in working out this valuable publication and I am sure the industry and the students of sugar technology will find the book to be a valuable guide.

Mangal Singh
President
STAI

3rd of August 2005
NEW DELHI

PREFACE

The System of Technical Control for Cane Sugar Factories in India revised by Prof. N.C. Verma & published by STAI in 1988 occupies a prime place in the Indian sugar industry. It is an essential companion of all the Sugar Technologists' and sugar factories.

Over these years the sugar industry in India has achieved phenomenal progress and from a sugar deficit country it has entered in the global market and registering it as a potential exporter. Now apart from Plantation White Sugar, Raw and Refined Sugar production has been started in many sugar factories. This has necessitated the factories to raise the technical working standards, specifcations of product quality and adopt uniform methods of control system and analysis conforming to international standards.

In order to enhance awareness in the Indian Sugar Industry, the STAI thought it fit to update, enlarge and revise the present edition of System of Technical Control for Cane Sugar Factories in India. I am grateful that the STAI reposed confidence in me and entrusted the task to me. My humble effort is before you in the form of 2nd revised edition of System of Technical Control for Cane Sugar Factories in India.

I have attempted to incorporate the latest methods of analysis, ICUMSA methods of analysis and the topics of current relevance to the sugar industry . It is impossible to accomplish such a job singly. I had the privilege of receiving guidance of my senior colleagues and contribution of fellow technologists.

I must acknowledge the books which I have referred to and drawn excerpts *viz.* Laboratory Manual for South African Sugar Factories, Published by South African Sugar Technologists' Association, ICUMSA Methods book and BIS specifications.

It is my prime duty to place on record my sincere thanks to Shri Mangal Singh, President, STAI, Prof. G.K. Shukla, Director, N.S.I. Kanpur and Shri P.K.N. Singh, Secretary, STAI for their guidance and advice from time to time in the task. The contributions of Dr. (Mrs.) V.S. Keskar, M/s Maarc Labs Pvt. Ltd., Pune for Chapter XIIA (Colour based technical control in sugar industry) and Dr. S. Kumar, Deptt. of Bio-Chemistry, N.S.I. Kanpur for his suggestions on effluent treatment are sincerely acknowledged.

The help and co-operation of Shri N. Mohan, Junior Technical Officer (Sugar Technology) in consulting literature, retrieving relevant material, it's compilation, preparation of manuscript and its proof reading is gratefully acknowledged. The team of Technical Assistants of Sugar Technology Division of N.S.I., Kanpur also deserves appreciation.

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Kanpur
August 2005

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CHAPTER – I

DEFINITIONS

CHAPTER – I

DEFINITIONS

1. **Added Water**
The water used in the imbibition process during milling of cane.

2. **Affined Sugar**
Sugar purified by affination.

3. **Ash**
Inorganic residue remaining after incineration and further distinguished as :

3.1 Sulphated ash - The residue remaining after incinerating the sample at 650^{0}C with sulphuric acid, also called gravimetric ash;

3.2 Carbonated ash - The residue remaining after incinerating the sample at 650^0 C in the absence of such treatment; and

3.3 Conductivity ash - It is the figure obtained by measuring the specific conductance of the solution of the sample.

4. **Absorbancy or Extinction Index**
A measure of the apparent colour of a solution as given by the formula :

$$a^* = \frac{A^*_s}{bc} = \frac{-\log 10 Ts}{bc}$$

Where a* = absorbancy or extinction index at 420 or as specified milli-microns wave length of light
A^*_s = Absorbancy of the solution
Ts = Transmittancy of the solution
b = cell length (cm)
c = concentration of total solids (g/ml)

This value multiplied by 1000 is reported as ICUMSA colour.

5. **Bagasse**
The residue obtained after crushing cane in a mill is known as bagasse. Depending on the number of the mill it is referred to as first mill bagasse, Second mill bagasse etc. After a diffuser, the residue is called diffuser bagasse. The final residue from a milling train or from the dewatering mills of diffusion plant is called final bagasse or simply, bagasse.

5.1 **Bagacillo**

Very small particles of bagasse separated either from mixed juice or from the mass of final bagasse serving as filter-aid or used for other purposes.

6. Boiling House Control Figures

6.1 **Boiling House Recovery (BHR)**

Sucrose (Pol) in sugar produced per cent Sucrose (Pol) in mixed juice.

6.2 **Basic Boiling House Recovery**

The theoretical boiling house recovery as calculated by the **s-j-m** formula in which **j** = gravity purity of mixed juice : **s** = 100 and **m**= 28.57.

6.3 **Boiling House Recovery**

The percentage ratio of the recorded boiling house recovery to the theoretical boiling house recovery as calculated by the **s-j-m** formula in which **s** =100, **j** = recorded purity of mixed juice and **m** = recorded purity of molasses.

6.4 **Boiling House Recovery (ESG)**

The percentage ratio of the ESG value of sugar produced, calculated as above to the sucrose in mixed juice (See Chapter IX).

6.5 **Boiling House Performance**

The percentage ratio of boiling house recovery ESG, to the basic boiling house recovery.

6.6 **Reduced Boiling House Recovery ESG (R85)**

The boiling house recovery ESG that would have been obtained under existing conditions if the factory had worked with a mixed juice of standard gravity purity of 85. This is found by the GUNDU RAO formula. (See Chapter IX.)

7. Brix

The per cent by weight of solid matter as indicated by the brix spindle or calculated from densimetric measurement converted to the brix scale. The term brix is also used in the same sense as gravity solids defined later. Since brix is considered as an entity and treated as a substance, terms like 'quintals brix' , 'total brix' and 'brix balance' are in use.

7.1 **Brix Spindle**

A hydrometer which reads directly the percentage by weight of sucrose in an aqueous solution of pure sucrose (g sucrose per 100 g solution) at the calibration temperature.

7.2 **Brix, Hydrometric**

The percentage by weight of solids in terms of sucrose in a sugar solution as indicated by the brix hydrometer, at the calibration temperature after referring the correction tables.

7.3 **Brix, Refractometric**

The per cent by weight of solids in solution as indicated by the sugar refractometer or as derived from the refractive index and reference to tables of equivalent per cent sucrose and refractive indices.

7.4 **Brix Free Cane Water**

The water associated with fibre in cane and bagasse. In some respects this sorption water behaves in a manner similar to water of hydration and is not available for dissolving sucrose, thus, does not constitute a portion of the juice proper. It cannot be separated from the fibre by mechanical means but is driven off at elevated temperature.

Brix free cane water or undetermined water = Cane - Fibre - Undiluted Cane juice.

7.5 **Cane Trash**

Material consisting of cane leaves, root - tops, dead sticks of cane and other vegetable matter from the field in which the cane was grown.

8. **Bulk Density**

The mass of material per unit of total volume occupied.

9. **Condensate**

Water obtained from various heat exchanger due to condensation of steam / vapours used for heating / boiling various process liquors.

10. **Conductance (Specific)**

Electrical conductivity of a solution in reciprocal ohms of a cube of the solution, one meter on each side. It is used as a measure of the ash content.

11. **Crystal Content**

The percentage by weight of total crystalline sugar present in massecuite, magma or any other similar material.

12. **Cush-Cush**

The material removable from mill juice by straining off the juice.

13. **Dilution Indicator**

It is a way of expressing the probable keeping quality of sugar and is indicated by

$$\text{Dilution Indicator} = \frac{\textit{Moisture\%sugar}}{\textit{100 – (Pol\% sugar + moisture\%sugar)}} \times \textit{100}$$

14. **Dry Substance**

The material remaining after drying the sample for a specific period or to a constant weight.

15. **E.R.Q.V. (Proportionate Purity Ratio)**
This expression denotes a value to indicate sucrose loss in the mills due to chemical/ biochemical action.

16. **Equivalent Standard Granulated (ESG)**
The quantity of dry pure sucrose (100 % sucrose, 100 purity) that could theoretically be obtained from sugar or other raw material using the SJM formula.

In the case of ESG of commercial sugar S=100, J = Purity of commercial sugar and M = recorded gravity purity of final molasses.

17. **Extraction**
That portion (usually percentage) of a component of cane which is extracted from the raw material during the process of milling/diffusion. Familiar components are juice Brix, Pol and Sucrose and the term 'extraction' is qualified, Extraction alone normally signifies Pol extraction accordingly.

17.1 **Mill Extraction (e)**
Sucrose (or Pol) in mixed juice per cent sucrose (or Pol) in cane.

17.2 **Reduced Mill Extraction (RME) Noel Deerr**
The recorded Mill Extraction reduced to a common basis of 12.5% fibre in cane (See Chapter IX).

17.3 **Whole Reduced Extraction (WRE) Mittal**
The recorded Mill Extraction reduces to a common basis of 12.5% fibre and 12.5% Pol in cane (See Chapter IX).

18. **Extraction Ratio (ER)**
The ratio of un-extracted sucrose (Pol) to fibre in cane.

$$ER = \frac{100 - \text{Mill extraction}}{\text{Fibre\% cane}} \times 100$$

19. **Fibre**
The water insoluble matter of cane and bagasse from which the brix free cane water has been removed by drying.

20. **Filtrate**
The liquid that has passed through the screens or cloths of the filters.

21. **Filter Cake**
The material removed from the process by filtrations including aid.

22. **Fly Ash**
Small particles of charred bagasse or ash entrained in the combustion gases carried out into the air from boiler furnace using bagasse as fuel.

23. **Gravity Solids**
The weight of solids calculated from brix determination.

24. **Gravity Purity**
The percentage by weight of sucrose in the Brix or gravity solids *i.e.*

$$\frac{\text{Sucrose\%}}{\text{Brix\% or gravity solids\%}} \times 100$$

25. **Green Run Off**
First syrup produced on centrifuging a magma.

26. **Imbibition**
The process in which water or juice is applied to bagasse to enhance the extraction of juice at the next mill. The term is also applied to the fluid used for the purpose.

27. **Invert Sugar**
A mixture of approximately 50 per cent glucose (dextrose) and 50 per cent fructose (levulose) obtained by hydrolysis of sucrose.

28. **Insoluble Solids**
The percentage by weight of solids in juice or other materials not soluble in water.

29. **Java Ratio**
The percentage ratio of sucrose (Pol) per cent cane to sucrose (Pol) per cent first expressed juice.

30. **Jelly**
The boiling mass which has been concentrated without graining to such a consistency that it may be expected to crystallize spontaneously upon standing.

31. **Juice**

31.1 All the dissolved Absolute juice solids in the cane, plus the total water of the cane; cane minus fibre.

31.2 **Carbonated Juice**
The carbonated juice after filtration in a carbonation process of clarification. The juice is termed 'first' or 'second' according to the stage of carbonation.

31.3 **Clarified Juice**
Clear juice obtained as a result of clarification process.

31.4 **Defecated Juice**
The juice obtained after liming in a raw sugar factory.

31.5 **Diffuser Juices**
The juice which is withdrawn from a cane, beet or bagasse diffuser.

31.6 **Filtered Juice**
The filtrates from the filters. If double filtration of mud is practised, the resulting juices are characterized as 'first filtered juice' and 'second filtered juice' respectively.

31.7 **First Expressed Juice**
The Juice expressed by the first two rollers of the milling tandem.

31.8 **Last Expressed Juice**
The juice expressed by the last two rollers of the milling tandem.

31.9 **Last Mill Juice**
The juice expressed by the last mill of the milling tandem.

31.10 **Mixed Juice**
The composite juice comprising primary and secondary juices which are sent from the milling plant to the boiling house.

31.11 **Primary Juice**
All the juice expressed before dilution begins.

31.12 **Residual Juice**
The juice left in the bagasse ; bagasse minus fibre.

31.13 **Secondary Juice**
The diluted juice which joins the primary juice to form mixed juice.

31.14 **Subsider Juice**
The juice decanted from the mud or settlings in the course of the clarification process.

31.15 **Sulphited Juice**
The juice emerging from the juice sulphiter after treating it with sulphur di-oxide gas.

32. **Lost Juice per Unit Fibre**
The Pol lost in final bagasse expressed in terms of absolute juice per unit fibre in cane, denoted by the V where

$$V = \frac{(1 - e)\,(1 - f)}{f}$$

e = Pol Extraction recorded per unit Pol in cane
f = Fibre per unit cane

33. **Maceration**
The process in which bagasse is steeped in an excess of water or juice. The term is also used as an alternative to the term 'imbibition'.

34. **Magma**
A suspension of crystals in saturated liquor made by mixing sugar with water, juice, syrup or molasses etc.

35. **Massecuite**
The mixture of crystals and mother liquor discharged from a vacuum pan massecuites are classified according to decreasing purity as first, second, third etc. or A,B,C or R_1, R_2, R_3 etc.

36. **Molasses**
It is the mother liquor in the massecuite which is separated from the crystals by mechanical means. The mother liquor separated before the washing of crystals begins is termed heavy molasses and that obtained on washing is termed light molasses. These are characterized as A,B,C or R_1, R_2, R_3 etc. according to the grade of massecuite from which they are obtained.

The heavy molasses obtained from the last grade of massecuite is termed final molasses or waste molasses.

37. **Modulated Reflectance Value (MR Value)**
It is the product of mean reflectance value of the four surfaces of the sugar in the square standard bottle and the grain size of the sugar in mm.

$MR = R \times G$

Where MR is modulated reflectance, R is the mean reflectance value of the four surfaces of the sugar bottle and G is the grain size of the sugar in mm.

38. **Mud or Settings**
The mud and solids drawn from the clarifiers and sent to the filters.

39. **Mud Solids**
Insoluble matter other than bagacillo in subsider mud, filter cake and associated materials.

40. **Net Titre**
An empirical value used as a measure of percentage of pure sugar, which may be recovered from a batch of raw sugar.

N.T. = Pol - (Reducing Sugars + 5 x Ash)

It may be mentioned that different formulae are in use in various countries.

41. **Non-Sugar**
Common overall term for substances contained in the raw materials and its products of the sugar industry, except sugar & water, usually indicated as Brix - Pol.

42. **Non-Sucrose**
Substances contained in raw material and its products except sucrose & water, usually indicted as dry substances - sucrose.

43. **Normal Weight (for Saccharimeter)**
This is defined as the weight of pure sucrose which when dissolved in pure water at 20^0 C to a final volume of 100 ml and tested at 20^0 C in a saccharimeter/sugar polarimeter under the conditions specified for the instruments, gives a reading of 100 degrees of the international scale (see 43.2).

43.1 **Normal Sugar Solution**
This is defined as 26.0160 gm of pure sucrose weighed in vacuo and dissolved in pure water at 20^0 C to a final volume of 100 ml. This corresponds to 26.000 gm weighed in air and dissolved in pure water at 20^0 C to a final volume of 100 ml.

43.2 **International Sugar Scale**
The Saccharimeter scale in which the 100^0 Z* corresponds to optical rotation of the normal solution of pure sucrose at the wave length of the green line of the mercury isotope 198Hg (546.2271 nm in vacuo) at 20^0 C in a 200 mm tube. This optical rotation is 40.777 +/- 0.0001^0 angular.

$$a \frac{20.00^0\ C}{546.2271nm} = 40.777^0 \pm 0.001$$

* The sugar scale is now to be characterized by ^{0}Z instead of ^{0}S.

(Note : To Convert ^{0}S to ^{0}Z multiply value of ^{0}S by 0.99971.)

44. **Nutsch Sample**
The sample of molasses which is separated from the masscuite with the help of Nutsch apparatus prior to the fugalling of massecuite in factory centrifugal.

45. **Organic Non-sugar**
The difference between the soluble solids and the sum of sucrose, reducing substances and ash.

46. **Overall Recovery**
The sucrose (Pol) in sugars % sucrose (Pol) in cane.

47. **Pol**
The value determined by direct or single polarisation of the normal weight solution in a saccharimeter. This term is used in calculation as if it were a real substance.

48. **Pol-ash Ratio**
The percentage ratio between Pol (sucrose) and ash.

49. **Preparation Index**
Percentage ratio of Pol leached out of the open cells of prepared cane to the Pol of disintegrated cane under specified conditions.

50. **Purity**
The percentage ratio of sucrose (or Pol) to the total soluble solids (or Brix) in a sugar product. The following terms are in general use :

50.1 $$\text{Apparent Purity} = \frac{\text{Pol\%}}{\text{Brix or gravity solids\%}} \times 100$$

50.2 $$\text{Gravity Purity} = \frac{\text{Sucrose\%}}{\text{Brix or gravity solids\%}} \times 100$$

50.3 $$\text{True Purity} = \frac{\text{Sucrose\%}}{\text{Dry Substance \%}} \times 100$$

(If the refractrometer is used for determining the apparent total solids the purities based on them must be designated accordingly to avoid confusion).

51. **Raw Value**
It is defined as the equivalent value of various sugars in terms of raw sugar testing 96^0 by the saccharimeter.

52. **Recovery**
Commercial sugar produced % cane.

53. **Reduced overall Recovery**

$$\frac{\text{Reduced Mill Extraction x Reduced Boiling House Recovery}}{100}$$

54. **Reduced overall Recovery (ESG)**

$$\frac{\text{Reduced Mill Extraction x Reduced Boiling House Recovery ESG}}{100}$$

55. **Reducing Sugars**
The term denotes the reducing substances in cane or its products calculated as invert sugar. These sugars reduce Fehling's solution & Tollen's reagent etc.

56. **Reducing Sugar - Ash ratio**
The percentage ratio of reducing sugars to ash.

57. **Reducing Sugars - Sucrose Ratio**
The percentage ratio of reducing sugars to sucrose.

58. **Refractrometric Dry Substances (RDS)**
Measurement of total solids in a sugar liquor / syrup using a refractrometer. For solutions containing only sugar & water, % RDS = % sugar. The temperature is usually controlled at 20^0

59. **Remelt**
A solution of sugar crystals in clarified juice or water or in any other process liquor prepared for further processing.

60. **Retention (Rotary Filter)**
The proportion of suspended matter extracted by the filter, expressed as a percentage of the suspended matter contained in the settlings.

61. **Saccharimeter**
A polarimeter equipped with the International Sugar Scale.

62. **Safety Factor**
A number designated to indicate the probable keeping quality of fresh raw sugar. This is also called 'Deterioration Factor'.

$$\text{Safety Factor} = \frac{\text{Moisture \% Sugar}}{\text{100 – Pol \% Sugar}}$$

63. **Seed**
Dry sugar or magma used as footing in the vacuum pan for boiling a massecuite.

64. **SJM Formula**
The formula gives the theoretically recoverable available sugar (sucrose or Pol) in the final product % sugar in the original material.

$$r = \frac{S\,(j - m)}{j\,(s - m)} \times 100$$

Where
r = recovery or available sugar
s = purity of final product
j = purity of original material
m= purity of the molasses produced

65. **Slurry**
Used for seeding low grade pans consisting of finally divided sugar crystals of 3-5 microns suspended in some specified liquor.

66. **Sugar**

66.1. **White Sugar**
Plantation white sugar prepared directly from cane or beet juice.

It refers to sucrose crystals centrifuged from a high-grade massecuite and suitably washed and dried to yield a sugar of 99.5^0 or higher Pol value used for direct consumption.

66.2 **Raw Sugar**
The sugar from high grade massecuites of a raw sugar factory or raw-house of a refinery. It is usually of 96 to 98 degree Pol.

66.3 **Brown Sugar**
The sucrose crystals including any adhering molasses recovered from a massecuite by mechanical means. They are termed as A,B,C or single or double cured sugars according to the grade of massecuite from which they are obtained.

66.4 **Refined Sugar**
Sugar prepared from raw sugar after affination, melting clarification, decolourization and re-crystallization having extremely low ash content.

66.5 **Demerara Sugar**
Very moist granulated sugar having a heavy molasses coating.

66.6 **Icing Sugar**
Finely ground granulated sugar containing not more than 5% starch or other antiquating agent. Also called as fondant sugar and fondant Icing sugar.

67. **Sugar Cane**
Basically tropical plant being cultivated in countries located between 35^0 N and S Latitudes. belonging to Poaceae family (Formerly it was in Gramineae).

68. **Sugar Beet**
Basically a temperate zone crop, belonging to goose foot (Chemopodiceae) family.

69. **Suspended Solids**
Solids in juice or other liquids removable by mechanical means.

70. **Syrup**
The concentrated clarified juice from the evaporator before crystallization has removed any sugar.

71. **Total Fermentable Sugars**
The quantity of sugars which is consumed by yeast & bacteria for its conversion to ethanol & other fermented products.

72. **Total Reducing Sugars**
The quantity of reducing substances (which reduces Fehling's solution & Tollen's reagent etc) present in any substance. It is normally represented as sum of sucrose, glucose & fructose.

73. **Total Sugars**
Sucrose plus reducing substances expressed as invert sugar.

74. **Undiluted Juice lost in baggase % fibre (Java)**
The undiluted juice lost in baggase. "Juice here means the undiluted last mill juice which has the same brix as that or primary juice and purity as that of last mill juice".

75. **Wash**
The diluted molasses thrown off by centrifugals during washing and /or steaming and collected separately.

76. **Winter - Carp Formula**

$$\text{Recoverable sugar} = 100\ s\ (1.4 - \frac{40}{J})$$

Where s = Purity of sugar produced
J = Purity of the original material

(This is the equivalent of the SJM formula with a molasses purity of 28.57 and sugar of 100 purity).

CHAPTER – II

DETERMINATION OF QUANTITIES

CHAPTER – II

DETERMINATION OF QUANTITIES

1. General Considerations

Correct weights of raw materials and finished products together with analytical data and proper records are essential for proper chemical control.

Direct weighing is standard practice and should be adopted. Measuring is to be resorted to only when the instruments available deliver results with sufficient degree of accuracy or otherwise under unavoidable circumstances.

The metric system of weighing and measuring as prescribed by the Government of India should be adopted.

The weighing and measuring devices should be carefully maintained, kept clean and calibrated as frequently as possible.

2. Calibration

2.1 Weighing

All the weight bridges or weighing scales for weighing cane, juice, imbibition water, filter cake, sugar, molasses etc. should checked and got stamped by the concerned state weights & measures department for accuracy, before the start of the season. The accuracy of these weigh bridges should again be checked periodically during the season.

Each factory should possess a set of standard certified weights from 1 Kg to 100 Kgs and with the aid of these, replacement weights should be prepared by substitute weighing on a sensitive scale. For this purpose old rails, mill couplings, filter press plates etc. should be used. With the help of these substitute weights, the weighing machines should be checked and standardized by noting down the weights placed and reading shown by the scale particularly near the normal working range.

Weighing machines with dial indicators and weight-printing devices, or computerized weigh-bridges are to be preferred for systematized cane delivery and accounting.

2.2 Measuring

If measuring equipments are used, they should be calibrated using pure water. From the weight of water discharged as weighed on an accurately calibrated weighing scale and its density at the temperature, the exact volume should be calculated. The volume should be expressed in litres. (See Table 1)

3. Materials whose quantities are to be determined

3.1 **Cane :** Directly weighed.

3.2 **Mixed Juice :** Weighed directly or measured and weight calculated.

3.3 **Imbibition Water :** Weighed directly or measured and weight calculated.

3.4 **Bagasse :** Calculated/Weighed directly*

3.5 **Filter Cake :** Weighed directly

3.6 **Sugar :** Weighed directly.

3.7 **Final molasses :** Weighed directly

3.8 **Condensates :** Measured

3.9 **Process Water :** Measured

3.10 **Process Chemicals etc. :** Weighed

3.11 **Steam :** Measured

3.12 **Power :** Measured.

4. **Weighing of Cane**

Harvested cane brought to the factory should be weighed along with accompanying trash, immediately before crushing. Therefore, the weigh-bridges for weighing cane should be installed outside the cane-yard but as near the cane carrier as possible. Separate weigh-bridges of adequate capacity should be used for bullock-carts, trucks/ tractors or lorries and wagons. They should be balanced several times a day.

The delivering vehicle loaded with cane is firstly weighed to get the gross weight. The empty vehicle after unloading cane is again weighed on the same weigh-bridge to get the tare weight. The weight of the cane is determined by deducting tare weight from the gross weight. The tare weight should be determined each time unless there is absolute certainty that the weight of the empty vehicle has not changed.

5. **Weighing of Mixed Juice**

As the factory control is based on mixed juice, particular care must be taken in ascertaining its correct weight. The mixed juice is to weighed before the addition of any chemicals or filtrate etc. Reliable tank scales should be used for the purpose. The bottom of the tanks should be made conical so as to facilitate quick & effective drainage. The tanks should be washed as often as possible to remove adhering foam, soil & dirt particles. A recording device should be provided which indicates the number of times a scale has been filled and emptied. Inlet and outlet valves must not leak, and they should be interlocked so that they do not open at the same time.

5.1 **Calibration of juice weight**

Automatic weighing scales of the Maxwell-Boulogne (M.B.) type delivering a constant weight of juice at each tip are in general use in India. They should be so installed as to be free from vibrations. The number of tips should preferably not exceed 24 per hour.

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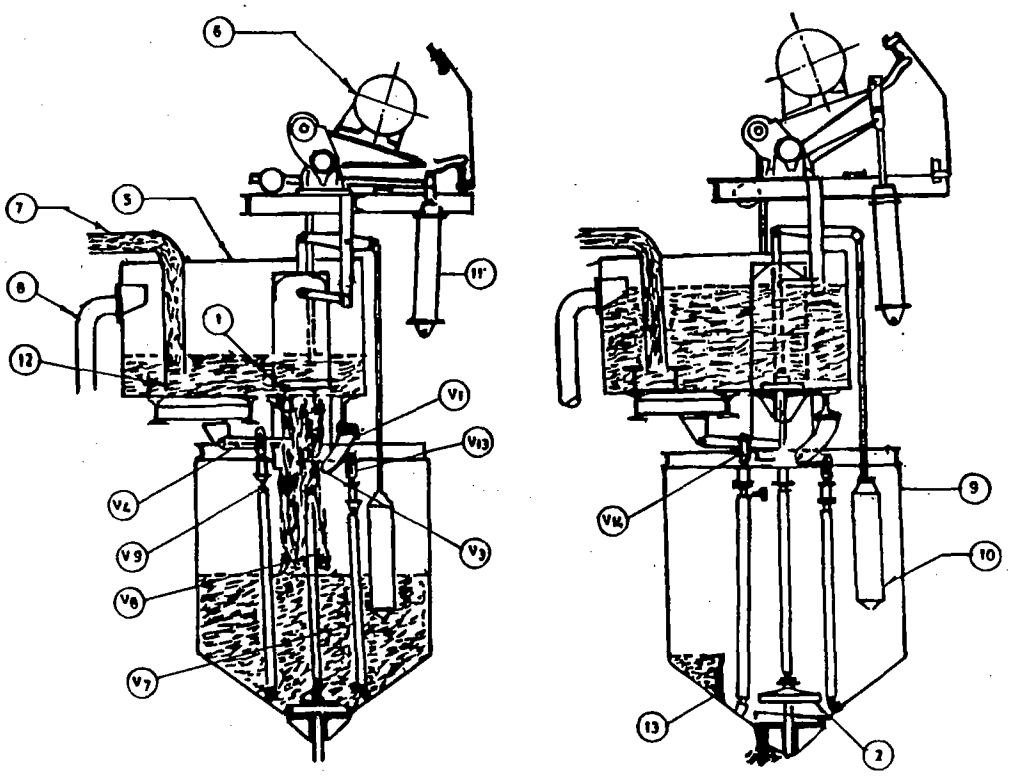
* Direct weighment is preferable for which necessary equipment should be installed only after its standardization.



S. NO.	DESCRIPTION		DESCRIPTION
1.	Valve Seat	V_1	Lever
2.	Valve Seat	V_3	Multiplying Lever
3.	Weigh Beam	V_4	Multiplying Lever
4.	Long Eye Bolts	V_9	Hinged Rod
5.	Supply Tank	V_7	Hinged Rod
6.	Counter Weight	V_{13}	Pin
7.	Supply Pipe	V_{14}	Pin
8.	Over Flow Pipe	V_8	Rod Connecting Valve 2
9.	Weigh Tank		
10.	Float		
11.	Hydraulic Buffer		
12.	Spreader		
13.	Baffle		

Fig 1 : Juice Weighing Scale

(*Courtesy :* Training manual for Sugar Mills by Mangal Singh)

Occasionally, the sensitivity of the scale may get disturbed and may show some erratic results. In order to achieve correct results for proper chemical control, it is imperative that this scale give accurate weighment. Hence, this liquid scale is counter checked with the help of cantilever scale provided below the automatic scale. Atleast, thrice in a shift, the counter check weighment should be done and average figure should be used for control purpose.

5.2 Correction in juice weight

Correction for dirt and suspended matter should be applied to the weight of the

juice because the subsequent analysis applies to the juice freed from these materials. The procedure for finding this correction is given below. It should be noted that the actual weight of the mixed juice should be reported as **gross weight**, and after the correction has been applied as **net weight**.

5.2.1 Dirt and Suspended matter Correction :

Quantities 50 to 100 ml of juice are composited for two hours as the juice enters the weighing tank and when sufficient quantity has been collected, the container is well shaken and the juice is transferred to a special decanting cylinder (Fig.2) through a 150 mesh sieve attached to a funnel.

The dirt is allowed to settle for one hour after which the juice is decanted. One litre of water is poured through the sieve into the cylinder, washing the residue in the funnel during the process. The sediment in the cylinder with the added water is shaken and allowed to settle for half an hour after which the supernatant liquid is decanted off. This is repeated three times. The sediment in the cylinder and the residue on the funnel are both collected on a weighed filter paper, dried at 100°-110°C and weighed. When dirt and bagacillo corrections are separately desired these portions are separately taken on weighed filter papers and estimated similarly. The weight of the dirt and suspended matter thus obtained divided by 10 gives the percentage correction to be applied. This should be determined once a day.

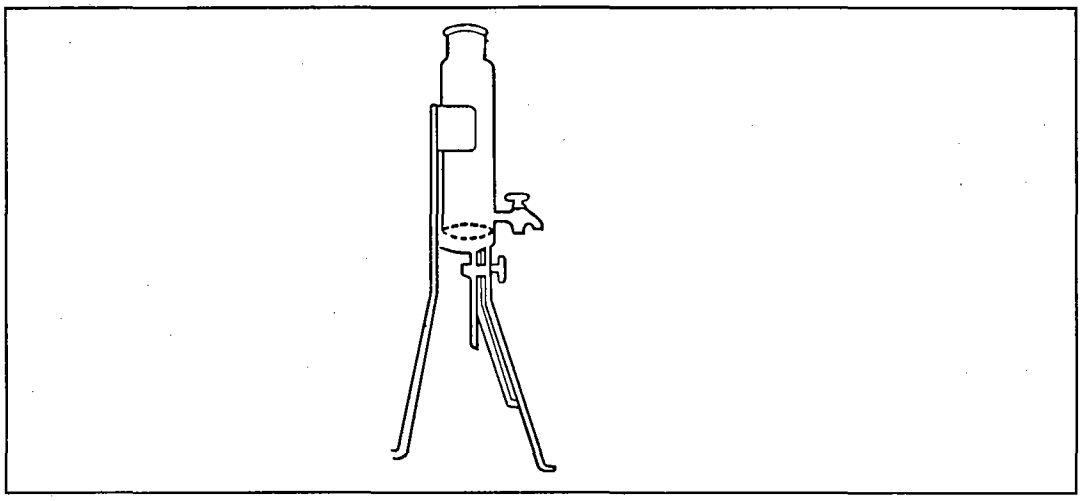


Fig 2 : Decanting Cylinder

6. **Weight of Mixed Juice by Measurement**

Where only measuring tanks are available these should be calibrated with pure water preferably by the discharge method. The sides and bottoms of the tanks should be of sufficient strength so as not to get deformed by the weight of the juice. They should have conical bottoms to enable complete and quick discharge and a sharp overflow to get the correct filling. The tank should not be directly connected to a pump but should discharge independently into a separate tank which is connected to the pump.

The temperature of the juice at the time of each measurement should be recorded and the weight calculated by multiplying the recorded volume with specific gravity

corresponding to brix corrected for the average temperature at which the measurements are made. (See Table III-A/III-B).

Corrections

When the juice is measured, corrections will have to be applied (a) for foam and (b) for dirt and suspended matter. The foam correction and the dirt and suspended matter correction may be determined once per day.

6.1 **Foam Correction**

One of the measuring tanks is thoroughly disinfected and filled with juice in the normal way and left for about half to one hour until one is sure that all the air has escaped. The water required to be added to bring the tank again to overflow is recorded. If P is the volume of the tank to overflow; Q is the volume of the water added then $\frac{Q}{P}$ x 100 represents the foam volume correction per cent juice measured.

6.2 **Dirt and Suspended Matter Correction**

The procedure is the same as in weighment, but instead of 1 kg of juice, one litre of juice is taken. The dry dirt and suspended matter from the filter paper are quantitatively collected in a measuring flask of 50 ml capacity. From a 50 ml burette filled with alcohol 20 ml are added and the dirt and suspended matter well shaken so that the air bubbles, if any, may escape. After this the flask is carefully filled up to the make with alcohol from the burette. The amount of alcohol left in the burette above the 50 ml mark indicates the volume of the dirt and suspended matter per litre of the juice. The volume thus obtained divided by 10 gives the percentage correction by volume.

The system does not ensure very accurate measurement of the mixed juice and hence no longer being practicised by the sugar factories.

In case juice flow measurement is to be resorted to, flow rate may be monitored by installing microprocessor based electromagnetic flow meter/mass flow meter which measure the volumetric flow rate & density of the juice very accurately.

7. **Weight of Imbibition or Added Water**

7.1 **By Weighment**

This should be obtained by weighing in tank scales and the same precautions should be observed as in the weighing of mixed juice. Great care must be exercised in this operation, as the weight of imbibition water is used to find the weight of bagasse. The weight of imbibition water must include any and all water entering the juice during the milling process.

7.2 **By Measurement**

As discussed in mixed juice case, in general, this method is not recommended, but it can be resorted to where no scales are available. The same precautions must be observed as in the measuring of mixed juice. Correct temperature measurement is particularly important. Ordinary water meters are unreliable and as such if metering

is resorted to, an electromagnetic flow meter should be provided to monitor, indicate and totalize the imbibition water flow rate.

8. **Weight of Bagasse**

Devices for direct weighing of bagasse based on load cell have not be standardized. They have been installed in one or two factories on experimental basis only and should be used only after perfecting the system. The weight of bagasse has, therefore, to be calculated from the fundamental equation.

Cane + Added Water = Mixed juice + Bagasse*

Weight of cane, added water and mixed juice being known, the weight of bagasse is obtained by difference. Direct weighment is preferable and is recommended.

9. **Weight of Filter/Press Cake**

To obtain total quantity of the Filter/Press Cake produced, if weighing of the entire production is not practicable. the sampling method given below may be resorted to.

9.1 **Filter Presses** (Plate and Frame Type). Cake from the middle and two end chambers of the filter press should be collected and weighed. The weight divided by three gives the average weight per chamber. This multiplied by the number of chambers in the press gives the weight of filter cake per press dropped. This multiplied by the number of presses dropped per shift gives the total weight of filter cake per shift.

9.2 **Rotary Vacuum Filter.** Cake adhering to one whole frame should be removed at regular intervals and weighed. At the end of a period the average weight of the cake is multiplied by the number of frames on the drum and the number of revolutions in the period. As an alternative a sample may be isolated by a cutter enclosing a known area. The portion removed is weighed along with other samples taken similarly at some intervals. Then the average weight of the known area can be used to calculate the output of the whole filter over a given number of revolutions per unit of time.

10. **Weight of Final Molasses**

10.1 **By Weighing**

Final molasses should be weighed directly before it is sent out to the storage tank. In case of manual batch weighing, scales of large capacity should be used for the purpose, so that, the number of weighings are reduced to a minimum. Tare weights must be determined at each weighing. Where automatic weighing scales are installed, the same procedure as prescribed for mixed juice may be adopted.

10.2 **By Measuring**

Molasses may be measured in receiving or storage tanks using the pneumercator. This consists of a delicately adjusted air chamber in the molasses tank

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* Loss of water from bagasse by evaporation is neglected. Entry of any water from that used for cooling of bearings should be avoided.

communicating with a mercury gauge calibrated for the particular tank. The hydrostatic head of the molasses actuates the diaphragm of the air chamber to record the pressure of the molasses independent of foam, occluded air, density or temperature. The gauge registers the quantity in desired units.

For running control purposes, however, actual weighment, directly after purging, is recommended.

11. **Weighment of Sugar**
Weighing of sugar should be done on platform scales for which the counterpoise should be set at a point corresponding to the weight of the standard sugar plus the average weight of the bag. The average weight of empty bag should be obtained by weighing fifty or a hundred bags, since individual bags are likely to show variation from the average. The scales should be frequently attended to for cleanliness and setting.

12. **Measurement of Condensate**
The steam consumption at the juice heaters, evaporators and pans is found by measuring the condensates by installing condensate meters which should be periodically checked for accuracy by collecting the discharge from the meters into a weighing tank or volumetrically calibrated tank.

13. **Measurement of Process Water**
The quantities of water used for processing at the pan floor (including molasses dilution), at the filters and centrifugals should be measured by flow meters, which should be checked for accuracy periodically.

14. **Weighment of Limestone, Coke, Lime, Sulphur and other process chemicals**
Actual weights should be determined by direct weighment.

15. **Measurement of Steam**
The quantity of steam generated by the boiler and consumed by the prime movers and in the boiling house should be measured in order to control the steam consumption of the plant. For the purpose reliable steam flow meters with IBR certification should be installed.

16. **Measurement of Power**
The factories should have system for measuring total power generated and consumed at various stations. For the purpose good quality KWH meters should be installed.

CHAPTER – III

ROUTINE ANALYSES

CHAPTER – III

ROUTINE ANALYSES

1. Analysis of Sugarcane

Pole and Fibre in the cane should be determined. Two methods are in vogue, the direct method and the indirect method. For routine factory control purposes only the indirect method is to be used. The direct method is in use in few countries and in those areas where payment of cane price is made on quality basis. It is also employed for finding out the maturity level of cane.

1.1 Pol per cent Cane

1.1.1 Pol per cent Cane (Direct Method)

Sampling of cane is to be done in such a manner as to obtain as representative a sample as possible. Core sampling or Grab sampling of whole cane or Hatch sampling of prepared cane is in use in some countries.

A known weight of the sample so obtained is then subjected to wet disintegration. The design of the disintegrator and conditions of test have been standardized. An extract is taken from the disintegrator and after dry lead clarification, polarized, in a polarimeter, by the conventional method.

For determination of Pol % cane, ICUMSA has also prescribed the method, the details of which are given in Chapter No. XII.

Rapipol Extractor Method

This method which is a wet-disintegration method fully described later under "Bagasse" analysis, can be used for determining the Pol or Fibre content of cane, directly.

(Note : Whereas in the case of bagasse the extraction is done for five to ten minutes; in the case of cane, the shredded or prepared cane is extracted on the Rapipol Extractor for 15 minutes).

1.1.2 Pol per cent Cane (Indirect Method)

The weights of cane, added water and mixed juice are taken from the factory records as determined daily and the weight of bagasse is found as follows:

Wt. of bagasse = Wt. of cane + Wt. of added water – Wt. of mixed juice.

Pol per cent mixed juice and Pol per cent bagasse are obtained from their respective analyses, the procedure for which is described later. Then Pol per cent cane is calculated as follows:

Pol % cane = Pol % mixed juice x Mixed juice % cane + Pol % bagasse x Bagasse % cane/100

Or

$$\text{Pol \% Cane} = \frac{\text{Tons Pol in mixed juice + Tons Pol in bagasse}}{\text{Tons cane}} \times 100$$

(See Chapter IX)

1.2 Fibre per cent Cane

1.2.1 Fibre per cent Cane (Direct Method)

After a representative sample of cane has been obtained, its sub-sample is further prepared for fibre determination in a shredder or Kruse slicer or in a chopping machine with a view to shredding it to a fine state of subdivision, so as to rupture the cells as completely as possible. Then either the washing method or the disintegration method is used.

(i) Washing Method

A known weight of the sample (200 g) is taken in a cloth bag, tied up with thread and the contents of the bag are washed in cold running water and squeezed occasionally. The bag is left in water for 24 hours. The bag is squeezed and water is pressed out. The insoluble mass is transferred to a tray and dried at 125^0-130^{0}C. Correction of loss in weight of the prepared sample is made as follows :

$$\frac{\text{Loss in weight}}{\text{Weight of prepared sample + loss in Wt.}} \times 100$$

Fibre % cane is calculated as follows :

$$\text{Fibre \% cane} = \frac{\text{Wt. of dried mass}}{\text{Wt. of sample + Loss in preparation}} \times 100$$

(ii) Disintegration Method:

A known weight of the sample (800-1000 g) is taken in the disintegrator and 2000 g of water is added. Sodium bicarbonate is added for pH correction and mercuric chloride for preservation. The disintegrator is run for 10 mins. 200 ml. of the extract is withdrawn for Brix and Pol determinations. Fibre is taken in a pan, washed out and kept for drying in an oven until constant weight.

Then,

$$\text{Fibre \% cane} = \frac{\text{Wt. of dried fibre}}{\text{Wt. of sample}} \times 100$$

For fibre per cent cane, by Rapi-Pol extractor see method described under bagasse. The fibrous material obtained from the machine is leached three times for a duration of five minutes each with five litres

of water. The fibrous material is then taken out, squeezed and dried in an electric oven to constant weight and fibre per cent cane is then calculated.

(iii) Hydraulic Press Method

This method, developed recently uses the Pinette-Emidecan type OB-102 hydraulic press (in conjunction with a core sampler) for the extraction of undiluted juice. A 1000 g sample is pressed for 5 mins. at 250 bar. Then by determining, bagasse per cent cane, moisture per cent bagasse, juice pol and juice brix, fibre per cent cane and also pol per cent cane can be calculated as follows :

Fibre % cane

$$\text{Juice \% bagasse} = \frac{\text{Moisture \% bagasse}}{1 - \frac{\text{Juice brix}}{100}}$$

Fibre % bagasse = 100 – juice % bagasse

$$\text{Fibre \% cane} = \frac{\text{bagasse \% cane x fibre \% bagasse}}{100}$$

Pol per cent Cane

Juice % cane = 100 – fibre % cane

$$\text{Pol \% cane} = \frac{\text{Juice \% cane x Pol \% Juice}}{100}$$

1.2.2 **Fibre per cent Cane** (Indirect Method)

For fibre determination by indirect method a sample of final bagasse is taken and analysed for Pol and moisture as per procedure described later under Bagasse analysis (Para 7 of this Chapter). A sample of Last Expressed Juice is also taken and analysed for Brix and Pol as described under analysis of Last Expressed Juice (Para 2.2). The purity of last expressed juice is considered to be the purity of residual juice in bagasse. Then fibre per cent cane is calculated as follows :

$$\text{Brix \% bagasse} = \frac{\text{Pol \% bagasse x 100}}{\text{Purity of residual juice}}$$

Fibre % bagasse= 100 – (Brix % bagasse + Moisture % bagasse)

$$\text{Fibre \% cane} = \frac{\text{Fibre \% bagasse x bagasse \% cane}}{100}$$

True average of three 8 hourly analyses will give the fibre per cent cane for the day.

1.3 **Expected recovery** (Lab Crusher Method)

For judging the maturity level of cane or evaluating its quality for sugar production, the cane may be analysed by the Laboratory Crusher method as given below :

A representative sample of whole fresh cane from the field is obtained at the laboratory and the lot subsampled by quartering. A known weight of the sample is then crushed immediately in a power driven laboratory crusher returning the bagasse at least three times and obtaining at least 65-70% juice extraction. The bagasse produced is weighed immediately and the weight of the extracted juice calculated by difference. The juice is analysed for Brix and Pol and bagasse for Pol only. Pol per cent cane and available sugar per cent cane are then calculated as follows:

(i) Pol % cane = [(Pol % juice x Juice % cane) + (Pol % bagasse x bagasse % cane)]/100

(ii) Available Sugar % cane = S – 0.4 (B–S) x F Where B and S are brix % and pol % of extracted juice respectively.

Value of factor F is dependent on values of (a) Fibre per cent cane (b) Brix free cane water per cent fibre and (c) Primary juice lost per cent fibre and can be calculated as follows:

Losses at various stages in processing cane in a factory depend upon.

(i) Fibre per cent Cane:
This affects the primary juice extracted in mixed juice. When it increases primary juice decreases.

(ii) Brix free cane water per cent fibre:
This figure tends to decrease the primary juice in cane.

(iii) Quality of Juice :
The non-sugars in juice *i.e.,* (Brix – Pol) affect extraction of sugar.

(iv) Primary juice lost in bagasse per cent fibre:
This varies with added water per cent cane and working of the milling plant.

(v) Virtual purity of waste-molasses:*
Besides the loss in molasses this takes into account the loss in filter-cake and undetermined loss.

Calculation

Assumptions : Brix free cane water % fibre = 20

Lost juice % fibre = 40

Fibre % cane = f

Then,

Primary juice extracted in mixed juice per cent cane

= 100 – 1.2 f - 0.40 f, and

Available sugar % primary juice = $[S - \frac{r}{100 - r} (B - S)]$

Where,

S = Sugar % Primary juice

B = Brix % Primary juice

r = Virtual purity of molasses

If r = 35, then, $\frac{r}{100 - r} = \frac{35}{65} = 0.54$

Then available sugar per cent cane

= Av. Sugar % P.J. x PJ extracted in MJ % cane/100

= [S – 0.54 (B – S)] x [100 – 1.2 f – 0.40 f]/100

= [S – 0.54 (B – S)] x [1 – 0.016 f]

or = [S – 0.54 (B – S)] x F

where F = 1 – 0.016 f. If f = 15 then F = (1 – 0.24) = 0.76

Thus the value of the factor F can be calculated for particular average values of Fibre per cent cane BFCW per cent fibre and Lost juice per cent fibre in respect of the cane variety crushed in the factory.

Alternately the estimated recovery (ER) from the juice analysis figures of cane crushed in the laboratory crusher can, to a close approximation, be calculated as follows:

$$\text{ER \% cane} = \frac{\text{Pol \% extracted juice x Java Ratio x Average Overall recovery}}{100}$$

The Java ratio and overall recovery figures taken for the above calculation should be previously determined from the average figures of the factory for the cane variety under test.

1.4 Preharvest Maturity Survey of Sugarcane

The survey for assessing the level of maturity of the cane crop meant to be crushed in the sugar factory, which should be started about six weeks before the start of the crushing season, is carried out by the Hand Refractometer method described below :

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* Virtual purity of waste molasses = $\frac{J - eJ}{1 - eJ}$, where 'J' is the gravity purity of mixed juice and e is the observed Boiling House Extraction (referred to unity)

Hand Refractometer Method

This method can be used for the standing cane crop in the fields. For each hectare of cane area, four workers are required to enter the field from four sides and extract juice samples from all the canes of at least two cane clumps each selected at random, by means of a stainless-steel Puncturing Needle (See Figure No. 3) to which is attached an acrylic 5 ml. pouch to receive the juice drops obtained on puncturing the internodes.

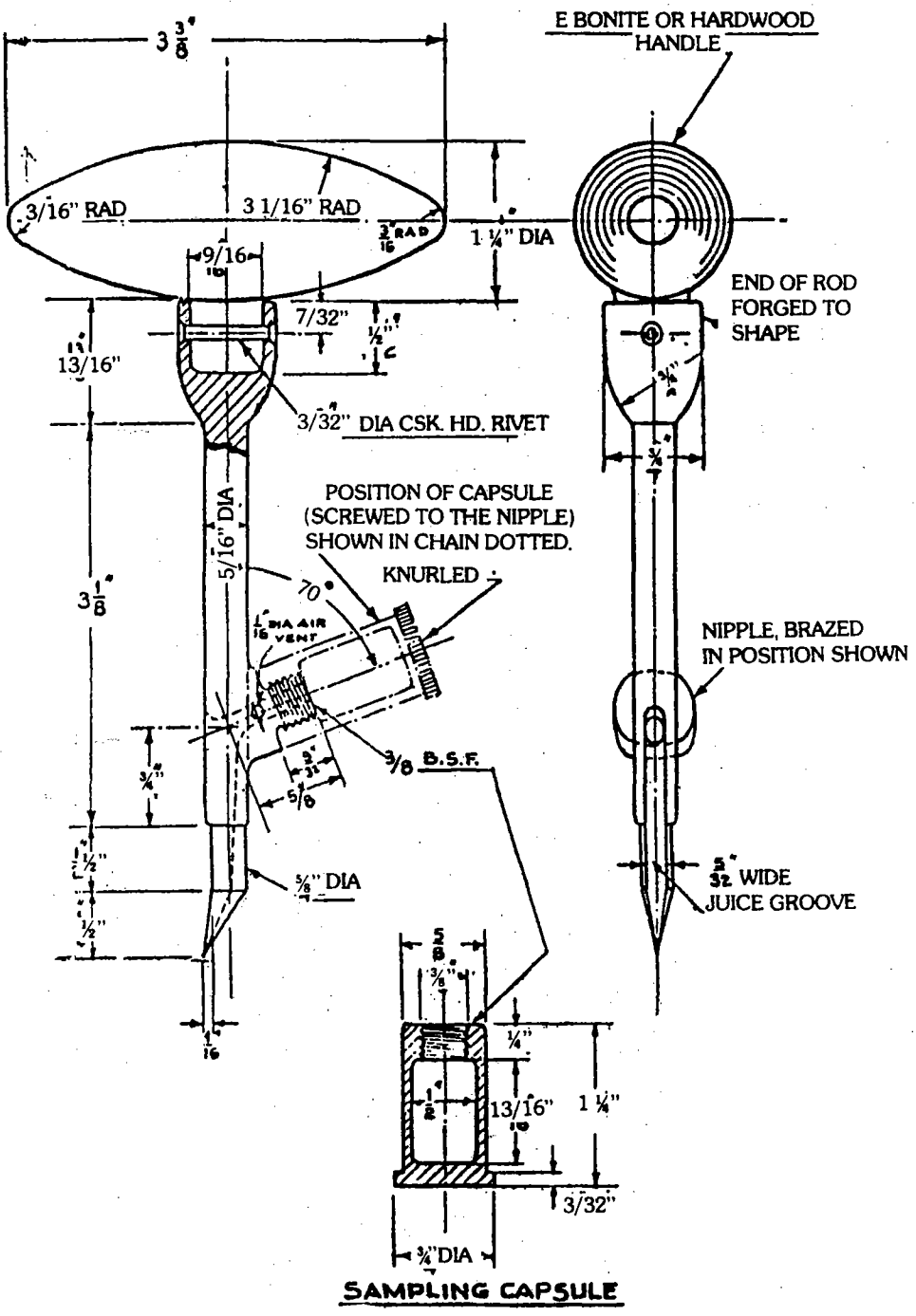

Fig. 3 : **Sugarcane Puncturing Needle**
Material : Stainless Steel, 1B-B

All the canes of the clump (3-6 canes) should be pierced in the middle internode of the cane after removing the dry leaf sheath. The juice collected in the pouch should be composited by pouring it into a clean dry stoppered 25 ml. polythene bottle. The brix of this juice should be determined immediately with the help of a hand-refractometer having an illuminated scale of 0-32^{0}C brix corrected for 20^{0}C and with the least count of 0.2. The zero-error of the refractometer should be checked frequently using distilled water.

A harvesting schedule should then be prepared based on descending order of recorded brix readings. Fields showing the highest brix should be harvested first and those registering lower brixes subsequently in descending order of brix values.

(Further information may be obtained from National Sugar Institute, Kanpur)

1.5 Checking the Quality of Cane

The quality of cane of a particular variety or received from a particular area, should be found out by actually carrying out a 'Mill Test" and not on the basis of stray samples of cane received at the laboratory. The quality of cane is denoted by (a) Pol per cent cane (b) Fibre per cent cane (c) Brix per cent primary juice (d) Purity of Primary juice and (e) Recovery of sugar obtainable from such cane.

Procedure for carrying out the Mill Test

(a) The test should be of 5-6 hours duration so as to afford at least four sets of samples, collected in duplicate of primary juice, mixed juice, last expressed juice and bagasse taken at hourly intervals, for necessary analysis. An average of 8 analyses will give reliable data for calculating out the quality parameters.

(b) Arrangements should be made for separate crushing of that quantity of cane which is normally crushed in 5-6 hours.

(c) Weigh-bridges should be cleaned and checked for accuracy before commencing the weighment of mill-test cane.

(d) Cane lying on the cane carrier and intercarriers from usual supply should be crushed out and the mill tandem quickly cleaned and steam disinfected.

(e) The mixed and dilute juices in the mill receiving tanks should be pumped out after stopping the imbibition water and before starting the mill test.

(f) The MB mixed juice weighing tank should also be emptied and cleaned out before the test.

(g) Samples for analysis should be collected in duplicate with necessary number of sample containers which should be arranged previously. Proper sampling is essential.

(h) Additional staff for collecting and analyzing the samples and necessary apparatus should also be arranged before hand.

(i) Start the crushing and open imbibition water after 15 mins. Application of imbibition water should be at the normal rate.

(j) The last lot of test cane on the cane carrier and intercarriers should be completely crushed out before resuming normal crushing.

(k) Mixed juice and imbibition water weight recorded during the test, should relate to the specific quantity of cane crushed for the mill-test.

(l) Quantity of juice in the pipe-line, before and after the test, will almost be the same and may be neglected.

(m) Pol per cent cane and Fibre per cent cane should be calculated out by the usual indirect method on the basis of the averages of eight sets of analytical data collected.

(n) Estimated recovery may be calculated by the formula

$$\text{ER \% cane} = \frac{\text{Pol \% cane x Average overall extraction of the factory *}}{100}$$

(o) The mill-test should be carried out at a time when the working of the factory is normal.

2. Juices

2.1 Primary Juice and First expressed Juice

Sampling :
Samples of primary juice or first expressed juice should be collected by automatic sampling devices. (see Appendix A). In the absence of automatic sampling, hand sampling carried out in a systematic manner and under strict supervision should be adopted. Every 15 minutes about 500 ml. of juice should be sampled from juice drainingg through the whole width of the first feed roller and the composite sample should be analysed after every four hours.

Preservation :
Mercuric chloride should be used in the proportion of 0.5 g per 1000 ml. of the sample. It is important that the full quantity of preservative is added in the beginning itself.

Note : Containers containing samples with mercuric preservative should be labeled as *Mercuric Poison.*

When brix is determined of the sample preserved with mercuric chloride, correction in the brix reading should be applied as given below:

100 mg mercuric chloride per litre substract	-		-	-	0.00
250 mg	-	do	-	-	0.03
500 mg	-	do	-	-	0.07
1000 mg	-	do	-	-	0.16

* recorded for previous run

Analysis:

Mix the composited sample thoroughly and pass through a 150 mesh sieve. Analyse for Brix and Pol as given below :

2.1.1 Brix : Fill the juice to overflow in a cylinder which should be perfectly vertical. Allow the air to escape by standing for 20 minutes. Alternatively, the air can be removed by applying vacuum. Gradually lower the standardized Brix spindle of the approximate range in position. When the spindle becomes steady, by which time it would also have attained the juice temperature, take the reading of the spindle keeping your eyes in line with the plane surface of the liquid. Note the temperature of the juice from the thermometer. The corrected brix of the juice is given by the reading on the hydrometer spindle + hydrometer correction if any + temperature correction as read from Table IV A or IV B corresponding to the recorded temperature.

2.1.2 Pol : Transfer about 200 ml. of juice into a 300 ml. Erlenmeyer flask which should have been rinsed with the juice before transferring. Add 2-3 g of Horne's dry subacetate of lead i.e. about one gram per 100 ml. of juice.

Note : Commonly used reagent for clarification is basic lead acetate also called subacetate of lead. The dry reagent is familiarly known as Horne's dry lead after its specific formulation prepared by Dr. Horne. There are several other formulations. It should generally be termed as simply "dry Lead". ACS specification of dry lead is as follows :

i) Water; not more than 1.5 per cent

ii) Total lead (as PbO); not less than 76 per cent

iii) Basic lead (as PbO); not less than 33 per cent

iv) Fineness; all to pass through 35 mesh Tyler. To pass through 115 mesh Tyler not less than 70 per cent.

Do not use more than what is absolutely necessary for good clarification, as excess of it causes error in the pol reading. Shake the flask well and filter, using dry filter paper and dry funnel. Cover the funnel with a watch glass during filtration. Collect the filtrate in a clean dry beaker. Reject the first few milliliters of the filtrate. Rinse a 200 mm pol-tube three times with a portion of the filtrate, fill the tube, seeing that there is no air bubble in it. Do not tighten the end caps of the pol tube too much as any stress in the cover glasses affects the pol reading. Then take the pol readings in a Saccharimeter. Take average of five readings as the pol reading. Then find the pol per cent juice by referring to Schmitz's Table (Table V-A/V-B), corresponding to the observed pol reading and uncorrected brix of the juice determined by the procedure described above.

Example :

i)	Hydrometric brix reading	15.0
ii)	Temperature of juice during brix measurement	30^0C

iii) Temperature correction from table IV-B for observed brix reading — 0.18

iv) Corrected brix — 15.18

v) Observed pol reading — 50.5

vi) Pol % juice
According to Table V-B, pol % for the pol reading of 50 is 12.31; for 0.5 it is 0.12
So total pol % (12.31 + 0.12) = 12.43.

vii) Purity of juice

$$\frac{\text{Pol \%}}{\text{Corrected brix}} \times 100 = \frac{12.43}{15.18} \times 100 = 81.88$$

2.2 Last expressed Juice

Sampling:
Last expressed juice should be sampled from the discharge roller of the last mill over the whole width of the roller at the same time as the sampling of bagasse is done. This should be cooled, composited and analysed every four hours.

Analysis:
Analyse for brix and pol as prescribed for primary juice.

2.3 Last Mill Juice

Sampling:
Sample is collected from the last mill juice gutter by a satisfactory automatic continuous sampling device, or by hand every 15 minutes. This should be cooled if necessary, composited and analysed every four hours.

Preservation:
Same as in the case of primary juice.

Analysis:
Analyse for brix and pol as prescribed for primary juice.

2.4 Mixed Juice

Sampling:
Mixed juice should be sampled by automatic devices (See Appendix A). In the absence of continuous sampling device, mixed juice should be sampled from each measuring or weighing tank, the quantity drawn being proportional to the volume or weight of juice in the tank. It should be such that the volume collected at the end of two hours is about 3 litres. The analysis should be for each two hourly composite sample.

Preservation:
Similar to primary juice.

Analysis:
Analyse for brix, pol, sucrose, reducing sugars, ash, P_2O_5 and pH.

2.4.1 Brix and Pol. As for primary juice.

2.4.2 **Sucrose:**

For determining sucrose, use the following double polarization method of Jackson & Gillis Method IV (Walker's inversion procedure). In this method neutral salts are used in the direct polarization to offset the effect of the acid on the invert polarisation.

Preparation of Samples:
Clarify about 200 ml. of juice using about 2 g of dry basic lead acetate according to procedure described for pol determination in primary juice. Delead any excess in the filtrate by using dry sodium or potassium oxalate to the extent that the filtrate gives no further precipitate.

Procedure for Direct Polarisation:
Pipette 50 ml. of the clarified solution into a 100 ml. flask and add 20 ml. of water. Then add 10 ml. of a solution of sodium chloride containing 231.5 g of sodium chloride per litre, mix with a swirling motion and make the volume upto the mark with distilled water washing down any liquid adhering to the neck of the flask. If a precipitate forms, filter. Polarise the filtrate in a 200 mm water jacketed tube at the room temerature which is recorded (t^0C). Pol reading multiplied by 2 is the "Direct" pol reading (P).

Procedure for 'Invert Polarisation':
For the invert polarisation adopt the following procedure. Pipette another 50 ml. of clarified solution into a 100 ml. volumetric flask and add 20 ml. of water. Insert a thermometer in the flask, then heat the solution in the second flask (in which a thermometer has been inserted) to exactly 65^0C by immersion in a hot, water bath maintained at $70\text{-}75^0C$ and after removing the flask from the bath, add immediately 10 ml. of hydrochloric acid (sp. Gr. 1.1029 or 24.85^0 Bx at $20^0/4^0C$). Mix the contents thoroughly by rotating and set aside the flask for 30 minutes. Cool the flask to the room temprature at which the direct pol observation was made (within 0.5^0C). Remove the thermometer from the flask washing down the adhering solution into the flask with a small stream of distilled water, then make the volume upto the mark with distilled water and filter. Polarise the filtrate at a carefully controlled temperature (the temperature at which the direct pol was taken) in a water jacketed 200 mm pol tube, taking an average of 5 readings. This multiplied by 2 is P_1.

The temperature of direct and invert polarisation as well as the temperature at which the volumes are made up should be the same and carefully controlled. These should as far as possible be at 20^0C.

Calculation:

The calculation is as follows:

Let, P = Direct polarisation reading at t^0C.

P_1 = Invert polarisation reading at t^0C.

K = Clerget divisor corrected for concentration and temperature.

The following Clerget divisor (K) for this method as recommended by the International Society of Sugarcane Technologists, is adopted, *viz;*

$$K = 132.63 + 0.0794\ (m-13) - 0.53\ (t-20)$$

Where m is the grams solid in 100 ml. of the polarizing solution and t is the temperature at which the reading is taken in ^0C, then

$$S = \frac{P-P_1}{K} \times 100$$, where S is the sucrose reading

By reference to Schmitz's Table V-A/V-B against the above calculated figure and the observed brix of the solution, the sucrose % is obtained.

Example:

Observed Brix of the sample = 16.5

Direct Pol reading (P) = 26.1 x 2 = 52.2 at t = 30^0C

Pol reading after inversion (P_1) = – 8.8 x 2 = – 17.6, Then

$P - P_1 = 52.2 + 17.6 = 69.8$

Then, Clerget divisor = 132.63 + 0.0794 (m-13)

Where m = grams of solids in 100 ml. of solution

For 50 ml. solution, m = (16.5 ÷ 2) x Sp. Gravity = 8.25 x 1.06759

= 8.8076

Clerget divisor = 132.63 + 0.0794 (8.8076 – 13)

Where 1.06759 is the Sp. Gravity corresponding to 16.5 brix at 20^0 (see table III-A).

Clerget divisor = 132.63 + 0.0794 (8.8 – 13)

= 132.63 – 0.0794 x 4.2 = 132.63 – 0.33 = 132.30

Temperature correction corresponding to 30^0C, to be substracted from the Clerget divisor = 0.53 (t – 20)

= 0.53 (30 - 20) = 5.30

(Values of temperature correction for t = 20^0C to 35^0C are worked out in the Table No. 1).

∴ Clerget divisor corrected for 30°C temperature

132.30 – 5.30 = 127.00. Then,

$$\frac{P-P_1}{K} \times 100 = \frac{69.8 \times 100}{127.00} = 54.99 \text{ say, } 55$$

Sucrose per cent according to the Schmitz's Table V-B against 6.5 Brix and 55 pol reading is 13.46. Thus sucrose per cent of sample is 13.46.

Substractive Temperature Corrections*

(Jackson & Gillis : Clerget Method IV)

Table 1

Temperature °C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
20	0.00	0.05	0.11	0.16	0.21	0.27	0.32	0.37	0.42	0.48
21	0.53	0.58	0.64	0.69	0.74	0.80	0.85	0.90	0.95	1.01
22	1.06	1.11	1.17	1.22	1.27	1.33	1.38	1.43	1.48	1.54
23	1.59	1.60	1.70	1.75	1.80	1.86	1.91	1.96	2.01	2.07
24	2.12	2.17	2.23	2.28	2.33	2.39	2.44	2.49	2.54	2.60
25	2.65	2.70	2.76	2.81	2.86	2.92	2.97	3.02	3.07	3.13
26	3.18	3.23	3.29	3.34	3.39	3.44	3.50	3.55	3.60	3.66
27	3.71	3.76	3.82	3.87	3.92	3.98	4.03	4.08	4.13	4.19
28	4.24	4.29	4.35	4.40	4.45	4.51	4.56	4.61	4.66	4.72
29	4.77	4.82	4.88	4.93	4.98	5.04	5.09	5.14	5.19	5.25
30	5.30	5.35	5.41	5.46	5.51	5.57	5.62	5.67	5.72	5.78
31	5.83	5.88	5.94	5.99	6.04	6.10	6.15	6.20	6.25	6.31
32	6.36	6.41	6.47	6.52	6.57	6.63	6.68	6.73	6.78	6.84
33	6.89	6.94	7.00	7.05	7.10	7.16	7.21	7.26	7.31	7.37
34	7.42	7.47	7.53	7.58	7.63	7.69	7.74	7.79	7.84	7.90
35	7.95	8.00	8.06	8.11	8.16	8.22	8.27	8.32	8.37	8.43

2.4.3 **Reducing Sugars :**

The Lane & Eynon (original) method is used.

Reagents :

(i) Neutral lead acetate solution: Dissolve 100 g of lead acetate in water and make the solution upto one litre.

* Apply temperature correction for the exact temperature at which invert polarization was read.

(From : Cane Sugar Handbook by Chen, Table 33, P. 1104).

(ii) Disodium phosphate, potassium oxalate solution: Dissolve 70 g of disodium phosphate (Na_2HPO_4 12 H_2O) in approx. 500 ml. of distilled water and 30 g of potassium oxalate ($K_2C_2O_4$ H_2O) in 200 ml. of distilled water, mix the two in 1000 ml. vol. flask and make up the volume to 1000 ml. mark.

(iii) Fehling's solution A : Dissolve 34.64 g of copper sulphate ($CuSO_4$, $5H_2O$) in water and make upto 500 ml.

(iv) Fehling's Solution B : Dissolve 173 g of sodium potassium tartrate ($KNaC_4H_4O_6$ $4H_2O$) in 300 ml. of water in a 500 ml. measuring flask.

Dissolve 50 g of sodium hydroxide (C.P.) in 50 ml. of distilled water. After cooling this, add it to the solution of sodium potassium tartrate and make up to 500 ml. mark with water.

(v) Methylene Blue Solution : Dissolve 1.0 g of pure methylene blue in distilled water and make the volume upto 100 ml.

(vi) Standard Invert Sugar solution for the standardization of Fehling's Solution : Dissolve 23.75 g of pure sucrose in about 120 ml. of distilled water. Add 9.0 ml. of conc. HCl and after gently mixing, the solution is allowed to stand at room temperature for 8 (eight) days. After that time it is made up to 250 ml. The solution is then checked for completion of hydrolysis by a Saccharimeter reading of – 11.80 ± 0.05° Z at 20°C. To 200 ml. of this solution (containing 10 g invert sugar per 100 ml. are added, with stirring, sufficient normal (N) sodium hydroxide solution (about 75 ml.) to ensure that the solution when diluted to 2000 ml. would have an acidity of about 0.001 N with respect to hydrochloric acid. Benzoic acid, 4 g, dissolved in warm water is then added and mixed and the solution cooled and made upto 2000 ml. This solution containing 1.0 g of invert sugar per 100 ml. is a stable stock solution which should be diluted immediately before use.

(a) *Standardisation of the Fehling's Solution :*
Take 50 ml. of the stock solution (containing 1 g/100 ml. of invert sugar) and dilute it with 200 ml. of distilled water and titrate using 10 or 25 ml. of the combined Fehling's solution as described below :

(b) *Preliminary test (by incremental titration) :*
10 or 25 ml. of Fehling's solution are pipetted into 300 to 400 ml. Erlenmeyer flask and treated cold with 15 ml. of the diluted invert sugar solution and heated to boiling over a wire gauze. After the liquid has been boiling for about 15 seconds it is possible to judge whether all the copper is reduced, by the bright red colour imparted to the boiling liquid by the suspended cuprous oxide. If it is judged that nearly all the copper is reduced, a few drops of methylene blue indicator are added, boiling is continued for 1 to 2 min. from the commencement

of ebullition and the invert sugar solution is added in small quantities, one ml. or less at a time, the liquid being allowed to boil between successive additions for about 10 seconds until the colour of the indicator is completely discharged. After the mixture of the Fehling's solution, with 15 ml. of invert sugar solution has been boiling for about 15 sec., if there still appears to be much unreduced copper a further 10 ml. of the invert sugar solution is added and the whole is allowed to boil for 15 sec., more and so on until it is considered unsafe to add further large increment of the invert sugar solution; boiling is then continued for 1 to 2 min., after which the indicator is added and the titration is completed by small additions of the sugar solution.

Having thus determined the amount of invert sugar solution required to reduce all the copper by this incremental method a second determination is made for accurate results by the standard method described below :

Precautions :

The flask should remain on the wire gauze over the Bunsen flame throughout the titration. In adding the sugar solution to the reaction mixture, the burette should be held in the hand and brought over the flask. The burette should be fitted with a small outlet tube bent twice at right angles permitting the body of the burette to be kept out of the stream while the jet is held over the flask. Burettes with glass stop cocks are unsuitable for this work.

(c) *Standard Method of Titration :*

Pipette 10 or 25 ml. of the mixed Fehling's solution into a 300 – 400 ml. Erlenmeyer flask and treat it cold with almost whole of the invert solution except one ml. or so as determined by the incremental method. The flask containing the cold mixture is heated over a wire gauze; after the liquid as begun to boil, it is kept in moderate ebullition for 2 min. and then without removal of flame, 3 to 5 drops of methylene blue indicator are added and the titration is completed by adding the sugar solution drop by drop in 1 min. further so that the reaction liquid boils together for 3 min. without interruption.

The indicator is so sensitive that the end point can be determined to within one drop of the sugar solution in most cases. To ensure that the indicator colour has disappeared, a white paper may be held behind the flask. If the indicator has not completely decolourised, the edge of the liquid will show a bluish tinge. The boiling in the flask should not be interrupted except for a second or two since the indicator undergoes back oxidation rapidly if air is allowed access into the flask. There is no danger of this as long as a continuous stream of steam is issuing out of the flask.

The factor of the standard solution as determined by titration will be –

$$F = \frac{\text{Titre x mg of Invert solution per 100 ml.}}{100}$$

Refer to Table VII-A for 10 ml. and VII-B for 25 ml. of Fehling's solution.

If the Fehling's solution has been accurately made, 25 ml. of it should require 24.80 ml. of the invert sugar solution containing 0.5 g of invert sugar/10 ml. corresponding to a factor of 124 mg. Any small adjustment required is made by the addition of a calculated amount of cupric sulphate or water followed by thorough mixing. Another standardization should be carried out after any such adjustment.

(d) *Determination of reducing sugar in the juice sample :*

Preparation of solution :
The juice solution is prepared of such a strength that 25 to 40 ml. (125 to 200 mg of reducing sugars) will be used in the titration.

If the juice sample contains no preservative it may be filtered directly through dry Kieselguhr and no lead or other clarification is used. Samples preserved with mercuric chloride may also be treated this way but juices containing formaldehyde should never be used for invert determinations since formaldehyde reduces copper. Before adding the Kieselguhr, dry sodium oxalate (about 0.25 g for each 100 ml. of juice) should be added to remove lime salts.

Titration :
10 or 25 ml. of mixed Fehling's solution is measured into an Erlenmeyer flask of 300 to 400 ml. capacity and treated cold with almost the whole of the sugar solution required to effect reduction of all the copper so that if possible no more than 1 ml. is required to complete the titration. The approximate volume of sugar solution required is ascertained by preliminary 'incremental' titration described under *'Standardisation of Fehling's solution'*.

The flask containing the cold mixture is heated over a wire gauze. After the liquid has begun to boil, it is kept in moderate ebullition for 2 min. and then without removal of the flame, 3 to 5 drops, of the methylene blue indicator are added and the titration is completed in 1 min. further so that the reaction liquid boils together for 3 min. without interruption. The indicator is so sensitive that the end point can be determined to within one drop of the sugar solution in most cases. The complete decolourisation of the methylene blue is usually sufficiently well indicated by the whole reaction liquid in which the cuprous oxide is constantly churned up, becoming bright red or orange. If there is doubt however, the flask may be removed from the wire gauze for a second or two and held against a sheet of white paper, the edge of the liquid will appear bluish if the indicator is not completely decolorized. It is not desirable to interrupt the boiling for more than a few seconds, since the indicator undergoes back oxidation rather rapidly when the air is allowed free access to the flask, but there is no

danger of this as long as there is a continuous stream issuing from the mouth of the flask.

(e) *Calculation of Reducing Sugars :*

Use Table VII-A for 10 ml. and Table VII-B for 25 ml. of mixed Fehling's solution. Under the proper heading for sucrose present in 100 ml. of the solution tested and opposite the milliliters of solution required to precipitate the copper as found by the titration (titre) is the invert sugar factor. The amount of invert sugar in 100 ml. of the test solution is the factor times 100 titre which is calculated in the column alongside the factor.

Example :

With juice at brix of 16.0 (1.06534 sp.gr.) and polarization of 14.0, a solution has been prepared to contain 25 ml. (25 x 1.06534 = 26.63 g) of original juice in 100 ml. of the prepared solution for titration. This solution therefore contains $\frac{14.0 \times 26.63}{100}$ = 3.73 g of sucrose (Pol) per 100 ml. Titration with this solution required 28.5 ml. to precipitate the copper in 10 ml. of Fehling's solution. From Table VII-A by interpolation between the 1 g and 5 g column for sucrose concentration, it is found that 100 ml. of the solution contains 171 mg of invert sugar. Therefore –

$\frac{100 \text{ x } 171}{1000 \text{ x } 26.63}$ = 0.684% is the reducing sugar in juice as invert sugar.

2.4.4 **Ash : (Sulphated)**

Take 50 g of juice in a well cleaned, heated, cooled and weighed platinum dish of 100 ml. capacity and concentrate to dryness on a water bath, then add 5.0 ml. of conc. Sulphuric acid (1.84 g/ml.) and heat the dish gently over a hot plate until the sample is carbonized. Place in a muffle furnace at 550°C for 2 hours and incinerate until all carbon is burnt off. Remove the dish from the muffle, cool and add a few more drops of H_2SO_4 then incinerate again at 650°C in the muffle for 30 minutes to ensure complete conversion into sulphates. Then cool the dish allow it to stand in a desiccator to reach room temperature and weigh. The weigh of ash obtained multiplied by two gives the % sulphated ash.

2.4.5 **Phosphate Content : (P_2O_5)**

Method I – Ammonium molybdate method

(a) Reagents

(i) Ammonium molybdate: Dissolve 25 g of ammonium molybdate in 200 ml. of warm water and filter. Dilute 280 ml. of concentrated sulphuric acid (arsenic and phosphorous free) to 800 ml. When both solutions are cool, add the molybdate solution slowly with constant stirring to

the sulphuric acid solution. Finally when the mixture has attained the room temperature, dilute it to one litre.

(ii) Stannous chloride solution : Dissolve 25 g of stannous chloride in one litre of dilute hydrochloric acid (one volume of hydrochloric acid + nine volumes of water). Store the solution in a glass bottle with delivery cock near the bottom, so that the upper surface of the solution which is protected from air by floating a layer of white mineral oil about 5 mm thick and the layer is not disturbed when the solution is drained out from the cock in drops.

(iii) Standard phosphate solution : For the stock solution 0.1916 g of recrystallised potassium dihydrogen phosphate (KH_2PO_4) is dissolved in water and made up to one litre. This solution contains 100 parts of phosphorous pentoxide per million parts. A second solution for use as a test standard is prepared by diluting 50 ml. of the stock solution to 500 ml. This contains ten parts of phosphorous pentoxide per million parts. As the solution is likely to decompose during storage because of microorganisms, the standard solution should be prepared at frequent intervals.

Procedure for analysis:

Dilute 5 ml. of the juice (This is to be adjusted according to the phosphate content of the juice) to 100 ml. in a measuring flask. Dilute 5 ml. of the diluted juice again to about 90 ml. mix well with 4 ml. of ammonium molybdate acid solution and six drops of stannous chloride solution and make finally upto 100 ml. Then compare the characteristic blue colour which develops with the standard in a colorimeter or in a pair of Nessler tubes. The colour fades after 10 to 12 minutes. Addition of one drop of stannous chloride restores the blue colour for another 10 to 12 minutes.

For preparing the standard for comparison, dilute 5 ml. of the phosphate solution to about 90 ml. with distilled water. Then mix it well with 4 ml. of ammonium molybdate solution and add six drops of stannous chloride solution and make upto 100 ml. If after 10 to 12 minutes the colour fades, it is restored by the addition of one drop of stannous chloride.

Calculation:
Five milliliters juice diluted to 100 ml. and 5 ml. of the diluted solution taken for test.

10 ml. standard is equivalent to 8.5 ml. test solution and 100 ml. standard contains 0.05 mg of phosphorous pentoxide, therefore,

100 ml. test solution contains $\frac{10}{8.5}$x0.05 = 0.058 mg of phosphrous pentoxide. This represents a quarter of a milliliter of juice, therefore, 100 ml. of juice contains $\frac{100}{0.25}$x0.0588 = 23.5 mg or 0.024 % phosphorous pentoxide.

Method II - Uranium acetate method:

Reagents:

(i) Uranium acetate solution : Dissolve 29.5 g chemically pure uranium acetate in distilled water, add 50 ml. chemically pure glacial acetic acid and make upto one litre.

Standardisation :

Standardize the uranium solution as follows: Dissolve 9.583 g of mono-basic potassium phosphate (KH_2PO_4) chemically pure, in one litre of water. Dilute 25 ml. of this solution to 100 ml. Add the uranium solution till a few drops withdrawn with a pipette give a brown precipitate on a drop reaction plate dusted with potassium ferrocyanide. Heat to between 90^0 and 100^0C and again add the uranium solution until a precipitate appears. Twenty five milliliter of the uranium solution should be required. Adjust to the correct strength, if necessary.

When a 100 g sample is titrated (100 ml. juice is usually taken as 100 g) each milliliter of the uranium solution is equivalent to 0.005 % of P_2O_5.

Procedure for analysis:

To 100 ml. of juice, add one milliliter of 10% ammonium hydrate solution, acidify with acetic acid and add 10 ml. of sodium acetate solution (100 g sodium acetate and 50 ml. glacial acetic acid per litre of distilled water). Titrate with the standard uranium solution using powdered potassium ferrocyanide as an indicator on a drop reaction plate. The solution will usually settle sufficiently to pipette a small portion of clear liquid for the end point determination. Nearly the whole of the uranium solution should be added in the cold and the titration finished at 90 - 100^0C.

When the solution contains the slightest excess of uranium, the addition of a drop of solution to the ferrocyanide on the drop reaction plate produces a brown precipitate of uranium ferrocyanide.

2.4.6 **pH :** This can be found out electrometrically or colorimetrically by using methyl red as indicator (see Chapter VII).

2.5 Clarified Juice

Sampling:
Clarified juice should be sampled by automatic devices. In the absence of continuous sampling device, clarified juice should be sampled every 15 minutes. This should be cooled immediately to prevent evaporation. Four-hourly composite sample should be analysed. The quantity of the sample at the end of four hours should be about 5 litre.

Preservation:
Same as for primary juice.

Analysis:
Analyse for brix, pol, sucrose, reducing sugar, ash, pH and CaO content.

2.5.1 **Brix and Pol :** Same as for primary juice.

2.5.2 **Sucrose :** Same as for mixed juice.

2.5.3 **Reducing Sugars :** Same as for mixed juice.

2.5.4 **Ash :** Same as for mixed juice.

2.5.5 **pH :** pH should be determined by electrometric method (glass electrode) or by colorimetric method, using bromothymol blue indicator.

2.6 CaO content :

Method I – Ammonium oxalate method:
To 100 ml. of clarified juice add a few drops of ammonia and then a few drops of concentrated acetic acid to make it slightly acidic. Then boil it and to the boiling solution add 30 ml. of 4% hot ammonium oxalate solution under continuous stirring and boil the liquid for another five minutes. Then set it aside for 4 hours for completing the precipitation. Filter, wash with hot water and dissolve the precipitate in dilute hydrochloric acid and precipitate again by adding ammonia and a little of ammonium oxalate. Then allow it to settle, filter and wash with hot water till free of oxalate by testing with silver nitrate solution. Then dissolve the washed precipitate in dilute (1:5) sulphuric acid and heat to 70^0C and titrate against 0.1 N potassium permanganate solution.

One millilitre of 0.1 N potassium permanganate = 2.8 mg of calcium oxide, if the titre value is 30 ml. the CaO content in 100 ml. of clarified juice = 2.8 x 30 = 84 mg. or in one litre of juice = 840 mg.

Method II – EDTA method :

Reagents :

(i) EDTA solution (Disodium salt of ethylene diamine tetra acetic acid of Merck quality). Weight accurately 6.6473 gms of EDTA into a beaker, dissolve the same in distilled water and make up the solution to 1000 ml. to obtain exactly M/56 solution.

(ii) Ammonia of C.P. quality.

(iii) Lead subacetate : Horne's dry lead.

(iv) Potassium ferrocyanide (Merck quality). Powder the crystals thoroughly.

(v) Potassium iodide – C.P. quality

(vi) Eriochrome Black T. (B.D.H. quality)

Weigh 0.1 g of Eriochrome Black T into a 100 ml. volumetric flask and dissolve the same in rectified spirit or absolute alcohol. Make up the volume with the same solvent and use it as the indicator.

Apparatus :

(i) Calibrated brix spindle

(ii) Brix Cylinder

(iii) Conical flasks of 250 ml.

(iv) Beakers of 100 or 250 ml.

(v) Funnels

(vi) Calibrated 10 ml. pipette

Procedure:

Take the juice, syrup or molasses samples as obtained from the factory. In case of juices, no dilution is required. In the case of syrups, dilute to 15^0 brix. In case of molasses, dilute to 5^0 brix. Transfer about 150 ml. of the juice or diluted solution into a conical flask. Clarify the solution by lead subacetate, as in Horne's method (Add if necessary some amount of active carbon). Transfer about 60 ml. of the clarified solution into a dry conical flask or flask previously rinsed with the clarified solution. Add powdered potassium ferrocyanide, little by little, till no further precipitate forms. Shake thoroughly and filter. Test the filtrate for absence of lead with potassium iodide. Collect the lead-free filtrate in a conical flask. Pipette out 10 ml. of this filtrate into a clean conical flask previously rinsed with distilled water and dried. Add a few (5-6) drops of liquid ammonia and a few drops (4-5) of the indicator solution when a pink red colour appears. Titrate against EDTA solution shaking the contents of the flask after every addition of EDTA solution. The end point is indicated by the sharp change of colour from red to blue. Note the volume of the titrant.

Calculation:

Let B be the Brix of the solution (diluted) and V the titre value of EDTA.

Then the amount of (Ca^{++} and Mg^{++}) is expressed as CaO.

= V x 100 mg per litre of juice or diluted solution.

$$= \frac{V \times 100 \times 100}{B} \text{ mg per litre per } 100^0 \text{ brix.}$$

3. **Syrup :**

Sampling :
Syrup should be sampled by automatic devices. In the absence of continuous sampling device, this should be sampled every 15 minutes and the sample should be cooled immediately to prevent evaporation. Four-hourly composite sample should be analysed. The sample collected should be about two litres.

Preservative :
No preservative is necessary for syrup.

Analysis :
A diluted solution of syrup is prepared by accurately weighing 400 g of syrup and adding to it 1200 g of water and mixing the whole thoroughly.

3.1 **Brix and Pol :**
Determine Brix and Pol of this solution by the same methods as given for Primary Juice. To arrive at the original brix and pol of syrup multiply the observed corrected reading of the dilute solution by four.

3.2 **Reducing Sugars :**
Determine these in the diluted solution of the unsulphured syrup by the same method as given for mixed juice. Multiply the result by four to get the reducing sugars of the original unsulphured syrup.

3.3 **Sucrose :**
Determine the sucrose content of the diluted solution by the same method as for mixed juice. Multiply the result by four to get sucrose per cent syrup.

3.4 **Ash :**
Weight about 15-25 g of syrup and determine sulphated ash by the same method as given for mixed juice.

3.5 **pH :**
Dilute the syrup in the proportion 1:3 with carbon dioxide free distilled water and determine pH electrometrically or colorimetrically. Indicator for finding the pH of unsulphured syrup is bromo thymol blue and for sulphured syrup methyl red.

4. **Massecuites :**

4.1 First, second, third and fourth massecuites:

Sampling:
These should be sampled from the receptacle before receiving the steamings. Each pan content of the massecuite dropped is to be analysed.

Preservative:

Not necessary for massecuite.

Analysis:

4.1.1 **Brix and Pol :** In the case of high grade massecuites weigh accurately 300 g of the massecuite and mix with 1200 g of the water and in the case of low grade massecuites, weigh accurately 200 g of the massecuite and mix with 1800 g of water. Mix the whole thoroughly. After making certain that all sugar crystals have been dissolved, determine the Brix and Pol of the diluted solution by the methods given for primary juice. Multiply the corrected readings of Brix and Pol of the diluted solution by five for high grade and by ten for low grade massecuites to arrive at Brix and Pol of the original massecuite.

Brix of the massecuite should preferably be determined by the pycnometer method described below:

Determination of brix of diluted massecuite/molasses solution using a specific gravity bottle (Pycnometer) :

Use a specific gravity bottle (50 - 60 ml. capacity) provided with a thermometer. Weigh the bottle together with its thermometer and cap, and then with water and note the temperature of water Tw^{0}C.

Empty the bottle and dry it and fill with diluted massecuite or molasses solution and weigh alongwith the thermometer and cap. Note the temperature T^{0}C.

(a) Let the weight of empty sp.gr. bottle + thermometer + cap = M_1 gm

(b) Let the weight of the bottle with water at Tw^{0}C=M_2gm
Then weight of water at Tw^{0}C = (M_2 – M_1) gm
Weight of water at 27.5^{0}C = (M_2 – M_1) + 0.0003 (M_2-M_1) x (Tw^{0}C – 27.5)

= Mw ..... gm

(where 0.0003 is the change in density by weight of one gm of water for one degree C change in temp at about 27.5^{0}C).

(c) Let weight of sp. Gr. Bottle + thermometer + cap plus test solution at T^{0}C = M_3 ... gm
Then weight of test solution at T^{0}C = (M_3–M_1) gm
Specific gravity of test solution at T^{0}C (uncorrected)

$$= \frac{M_3 - M_1}{Mw}$$

Brix, uncorrected, may be found from Table III B.

Corrected brix may be found from Table IV-B.

4.1.2 **Crystal Content :**

Crystal per cent in massecuite is calculated as follows:

$$\frac{\text{Massecuite Purity} - \text{Molasses Purity}}{100 - \text{Molasses Purity}} \times \text{Solids \% Massecuite}$$

Purities of massecuite and molasses are calculated from Brix and Pol determinations made according to methods described under Massecuite and Molasses analyses respectively. The molasses for this purpose is extracted with the help of HSPA water jacketed Massecuite Filter shown in Fig. 4A or the Nutsch Apparatus shown in Fig. 4B.

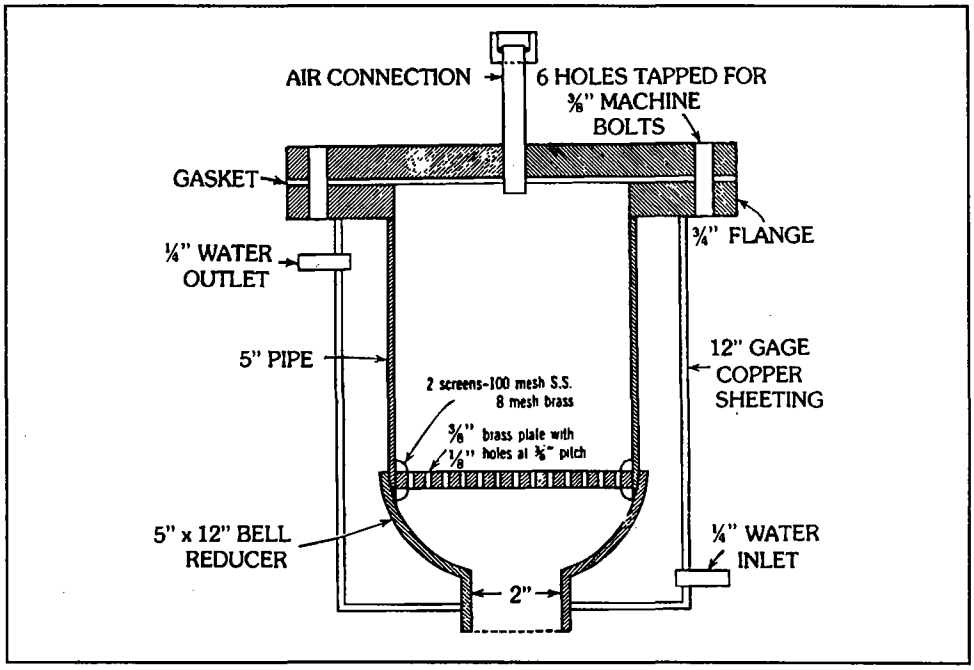

Fig. 4A : **HSPA Water-jacketed massecuite filter**

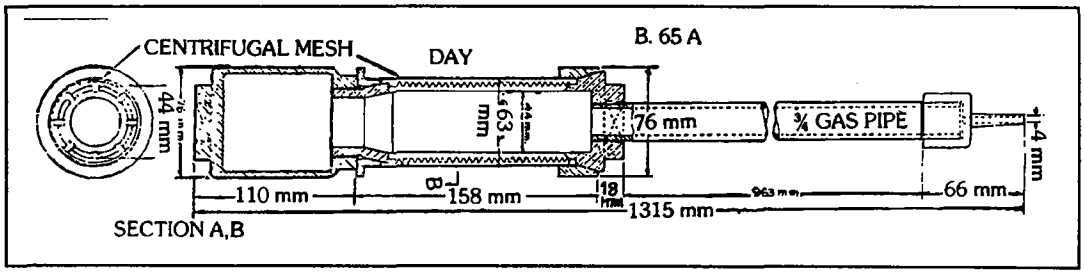

Fig. 4B : **Nutsch Apparatus**

4.2 **Final Massecuite :**

4.2.1 **Saturation Temperature :**

In order to control the cooling and reheating process of final grade massecuite, it is necessary to determine Saturation temperature.

Apparatus
Saturascope

Procedure

(i) Place a small quantity of the massecuite between two micro cover glasses. Squeeze them together gently until it spreads out into a thin uniform layer.

(ii) Remove the glass cover of the Saturascope and place the micro cover glasses containing the sample in the center of the stage, then replace the glass cover.

(iii) Focus the microscope and adjust the stage until a crystal with sharp edge comes into view and the crystal is in sharp focus.

(iv) Raise the temperature in the Saturascope by about 2^0C per minute by gradually raising the voltage of the variable transformer until the crystal under observation just begins to melt. Note the temperature.

(v) Repeat the above procedure on a second sample, this time raising the temperature rapidly within about 3^0C of the temperature recorded above. Then increase the temperature very slowly until the crystal begins to melt. The crystal edge will start becoming wavy or pitted or the sharp edge will round off. Note the exact temperature. This is the saturation temperature of that massecuite.

4.2.2 **Viscosity :**

Apparent viscosity of final massecuite may be determined by the Pipeflow or Orifice Plate methods described later in this chapter under Section 5.2.7.

5. Molasses :

5.1 Intermediate Molasses

Sampling:

These are sampled from the respective storage tanks when they are fully and properly mixed. The sample is better taken by inserting a long pipe with a bottom closing device by which a sample throughout the depth of the liquid in the tank is drawn. When control over boiling and curing is required, occasional samples direct from the centrifugals should be taken.

For studying the progress of crystallization during cooling in the crystallisers as well as for general process control purposes, the use of Nutsch apparatus is recommended.

5.2 Final Molasses

Sampling :

The final molasses from each strike is analysed for Brix and Pol. Aliquots from such samples are separately collected and composited. Twentyfour-hourly composite

sample constitutes the daily sample. Samples should be taken at the weighing or measuring tanks, the quantity drawn being proportional to the weight or volume of molasses in the tank. Continuous sampling can be done by means of a drip pipe located in the discharge line of the molasses pump.

Preservative:

Not necessary.

Analysis:
Weigh 200 g of the sample in a wide mouthed enameled mug, add 1800 g of distilled water and thoroughly mix the contents till the solution becomes homogenous.

5.2.1 Brix:
Determine the Brix of the dilute solution as in primary juice. Multiply the Brix thus determined by ten to get the brix of the sample of final molasses. The pycnometer method described under 'Massecuite' can also be used.

5.2.2 Pol:
Determine the pol of the dilute solution as in primary juice, using however three grams of dry basic lead acetate for clarification. Multiply the pol thus found by ten to get the pol of the sample of final molasses.

5.2.3 Sucrose:
Determine the sucrose % of the diluted solution by the Jackson & Gillis method IV (Walker's inversion procedure) described below:

Weigh two normal weights of the 1:1 solution (or one normal weight of the original molasses) into a 300 ml. flask, make to mark and mix. Pour about 100 ml. of the solution into a cylinder and add sufficient Horne's dry lead to clarify, avoiding an excess. A weighed amount can be prescribed for routine work, 6-8 g being sufficient for cane molasses. Mix by violent shaking and filter. Deleading is not essential. Pipette two 50 ml. portions of the clear filtrate into two 100 ml. flasks and add 20 ml. of water to each flask.

To one portion add 10 ml. of a solution of sodium chloride containing 235.1 g per litre; make to volume at the temperature at which the observations are to be made and polarize in a water jacketed 200 mm tube. Reading calculated to normal weight basis = P.

To the other portion add hydrochloric acid and invert as follows. Insert a thermometer in a flask and heat by immersing in a hot-water bath until the temperature is exactly 65°C. Remove the flask from the bath, add 10 ml. of hydrochloric acid (1.1029 sp.gr. at 20°/4°C = 24.85 brix), mix by rotating and set aside for 30 min., cool and make to volume at the temperature at which the observations are to be made. Polarise in a water jacketed 200 mm tube with temperature carefully regulated to the same as that for direct polarization. Reading is calculated to normal weigh basis = – P^1

Then

$$S = \frac{100\ (P - P^{I})}{132.63 + 0.0794\ (m - 13) - 0.53\ (t - 30)}$$

Where,

S = sucrose %

P = direct reading calculated to normal weight basis

P^{I} = Invert reading calculated to normal weight basis

t = temperature at which readings are taken

m = grams of solids in 100 ml. of invert solution as read

5.2.4 **Reducing Sugars**

This, in molasses, should be determined by the Lane and Eynon Constant Volume Procedure described below:

Reagents:

(i) Fehling's solutions

(ii) Methylene blue solution, 1%

(iii) Standard invert sugar solution

(iv) EDTA solution

Reagents (i) to (iii) are prepared as indicated under Mixed Juice analysis for reducing sugars.

Reagent (iv) is prepared by dissolving EDTA (disodium salt) 20 g in distilled water and making upto 500 ml.

Apparatus

In addition to the usual laboratory glassware, the method requires a suitable heating appliance for a 400 ml. boiling flask. This may be of any form, heated by electricity or gas, but must be adjusted in such manner that 75 ml. of water is heated from room temperature to boiling point in 2 min 30 s ± 5 s.

It may be advantageous to provide a white background to the assembly of heater and boiling flask in order to facilitate the detection of the end-point of titration.

Preparation of test solution:

The concentration of the test solution should be so arranged that its invert sugar concentration lies between 250 and 400 mg/ml., i.e.,

about 2 g cane molasses/100 ml.. When dealing with molasses solution, interference from calcium is overcome by adding 4 ml. of EDTA solution [reagent (iv)].

Standardisation of Fehling's Solution

Fehling's solution A (50 ml.) and Fehling's solution B (50 ml.) are pipetted into a clean, dry beaker immediately before use and well mixed. Solution A must be added to solution (B) and not the reverse. A burette is rinsed and finally filled with standard invert sugar solution (0.25 g/100 ml.). Mixed Fehling's solution (20 ml.) is pipetted into a 400 ml. boiling flask with distilled water (15ml.). After running in standard invert sugar solution (39 ml.) from the burette, small amount of pumice is added and the contents of the flask mixed by gentle swirling.

The flask is placed on the heater and brought to boil in 2 min.

30s ± 5s. The flask must not be removed from the heat source during the test procedure. The solution is allowed to boil for precisely 2 min. at which stage methylene blue solution (3 or 4 drops) is added to the contents of the boiling flask. The solution should assume a distinctly blue colour and, if the original reddish colour persists, this indicates that the solution is deficient in copper. In this event, the test is repeated, starting with less invert sugar solution, in order to establish and excess of copper. If the solution remains blue, the test is continued by the addition of standard invert sugar solution from the burette in small increments, initially of 0.2 ml. then of 0.1 ml. and finally in single drops, until the end-point is reached; this is indicated by the disappearance of the blue colour imparted by the methylene blue and the solution assumes the reddish colour associated with a suspension of cuprous oxide.

During the titration, the solution must not be allowed to cease boiling and, therefore, the flask must not be removed from the heater during the test.

The final titre is noted. The end-point should be reached at the end of the boiling period of 3 min ± 5s.

The final volume of the mixture after titration should be 75 ml., this figure neglects loss of water by evaporation which, under standardized boiling conditions, remains constant. If the Fehling's solution contains the correct amount of copper, then 20 ml. should require 40 ml. of 0.25% standard invert sugar solution, equivalent to 100 mg invert sugar.

When necessary, the strength of the Fehling's solution should be adjusted by the addition of copper sulphate solution or of distilled water, in order to ensure the correct titre of 40 ml.

Preliminary test

A preliminary test should be carried out to establish the approximate titre and to ascertain the quantity of water to be added to the 20 ml. of Fehling's solution to ensure a final volume of 75 ml. at the end of the titration.

The procedure is the same as for the standardization of the Fehling's solution, but using molasses solution instead of standard invert sugar solution i.e., molasses solution (25 ml.) is run into the flask, distilled water (15 ml.) and a little pumice added, the contents of the flask gently mixed and allowed to boil for precisely 2 min. and then titrated.

If the reddish colour in the flask persists after addition of 3 or 4 drops of methylene blue solution, it indicates that the molasses solution was too concentrated. In this case, the test must be discarded and repeated using a less concentrated molasses solution.

If more than 50 ml. of molasses solution are required, this indicates that a more concentrated molasses solution should be used.

The quantity of water to be added is calculated by subtracting the volume of Fehling's solution (20 ml.) and of molasses solution from 75 ml.. Once this is established, the following procedure is used.

Analysis:

Fehling's solution (20 ml.) is pipetted into the boiling flask and the required amount of water added.

An initial addition of molasses solution of 1.0 ml. less than the observed titre in the preliminary test is made. A few fragments of pumice are added and the contents of the flask mixed by gentle swirling. The flask is placed on the heater and the titration completed as in the preliminary test.

The end-point should be reached at the end of a boiling period of 3 min. ± 5 sec.

Calculation :

If no sucrose is present, the reducing sugars content of the molasses is given by :

$$\text{Per cent reducing sugars} = \frac{1000}{C \times T}$$

Where C = concentration of molasses test solution (g/100 ml.) and T= titre (ml. of molasses solution used).

When sucrose is present, a correction factor should be applied *i.e.*,

$$\text{Per cent reducing sugars} = \frac{1000 \times F}{C \times T}$$

Where C = concentration of molasses test solution (g/100 ml.), T = titre (ml. of molasses solution used) and F = correction factor

Values of F vary with the sucrose content (S) of the test solution and are shown in following Table No. 2

Correction factors for constant volume, Lane and Eynon method

Table No. 2

Sucrose (g) S	Correction factor F
0	1.000
2.0	0.946
4.0	0.912
6.0	0.887
8.0	0.865
10	0.849

Intermediate values of F may be calculated from the formula:

$F = 1 - 0.292\ S^{2/3}$

The value of S (approximate sucrose content) may be estimated by polarization after clarification with basic lead acetate.

5.2.5 **Total Reducing Sugars (Total Sugars):**

Total reducing sugar may be determined by the above method (Lane & Eynon constant Vol. Method) after inverting the molasses solution under test by the Walkers acid inversion procedure as described for Sucrose analysis of final molasses (by Jackson & Gillis No. IV method), *viz.* add 10 ml.. of hydrochloric acid of 24.85 brix to the previously heated test solution in the water bath upto 65°C, mix by rotating and set aside for 30 minutes, cool and make to volume (100 ml.).

5.2.6 **Sucrose:**

By Chemical Method:

The optical method for the determination of sucrose described earlier is liable to considerable error in the case of low purity materials. The chemical method gives more reliable results. This method involves the determination of the original reducing sugar content of the sample followed by another reducing sugar determination after the sucrose present has been inverted to

reducing sugars *viz.* total reducing sugars described above. Then, Sucrose per cent = (per cent Total reducing sugars after inversion – per cent Reducing sugars before inversion) x 0.95.

5.2.7 **Viscosity:**

The coefficient of viscosity (μ) is defined as the force per unit area *viz.* dynes/cm^2 required to maintain unit difference of velocity, *i.e.* 1 cm/sec. Between two parallel layers 1 cm. apart. The unit 1 dyne/sec/cm^2 is called 'Poise'. For many liquids the difference in velocity of the two layers one cm. apart is always proportional to the force applied or in other words, the rate of shearing is at all times a linear function of the shearing stress applied. Such liquids are said to be perfect or Newtonian in their flow properties and the ratio of their 'shearing stress' and 'shearing rate' will directly give a measure of their 'viscosity'.

Other liquids however offer an initial resistance to flow until the stress is sufficient to overcome the initial resistance after which uniform shearing will take place. Fluids of this type exhibit some plasticity.

It is found that 'molasses' exhibits pseudo plasticity only to a slight degree and the effect becomes even less pronounced with increase in temperature. Thus, for all practical purposes viscosity of molasses may be determined by measuring the 'shear stress' and shear rate.

This has been done by the 'falling ball method' and the rotating cylinder method. In the former the shearing stress applied is consent whereas in the latter shearing stress can be varied. ICUMSA officially accepted the rotating cylinder method (using HSPA/Brookfield viscometers).

Simpler methods for semi-quantitative measurements for process control purposes, have since been suggested *viz.* 'the Pipeline Viscometer' method and the Orifice Plate method which are as follows :

(i) *The Pipeline Viscometer method:*

Sketch of an instrument designed by the University of Queensland is given in Fig. 5A below: As readymade instruments of this type are not available, it may be fabricated locally.

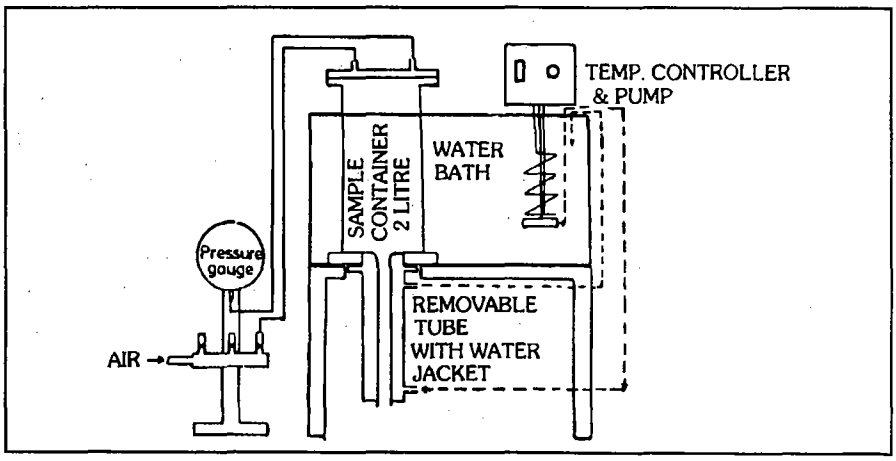

Fig. 5A : **Pipeline Viscometer**

It consists of a cylindrical reservoir of 2 litre capacity filled with an easily removable top cover and a tube of 18.8 mm dia. And 204 mm length attached to the bottom of the reservoir which is contained in a constant temperature bath, the tube also having the water jacket. The top cover is filled with a pressure application system with a gauge.

Procedure:

Fill the sample in the cylindrical reservoir, heat the water bath; when the desired temperature has been reached the air pressure is set as required and the molasses is allowed to flow through the tube. When the flow becomes steady, the flow rate is determined by collecting the discharge over a measured time interval. Record (i) pressure applied (ii) sample weight collected (iii) the time interval and (iv) the head of the molasses before and after the run. The viscosity can then be determined as in the equation given below:

$$\mu = \frac{D^2 \Delta P}{32\, LV}$$

Where μ is the viscosity in PaS, D the dia. of the tube, L the length of the tube, V the average velocity in the pipe and ΔP is the pressure difference. The method is applicable to massecuites also.

(Ref. J.N. Ness, Proc. ASSCT (Queensland) 1980 p. 195-200)

(ii) *Orifice Viscometer method:*

This apparatus consists of an open rectangular perspex box 24 cm wide x 48 cm long x 30 cm deep. A thin but rigid metal insert is fitted into a close fitting slot across the middle of the box to provide an orifice of appropriate size. The material is circulated through the orifice until a steady state is reached as shown by the constancy of levels on both sides of the orifice. At steady state the levels are measured with a sharp prob attached to a vernier scale which is adjusted until it just touches the surface of the flowing liquid. The levels are measured as close to the orifice plate at possible. Flow rate is measured by weighing the quantity of the fluid discharging in a given time. All measurements are to be made under gravity and at constant temperature. Orifices of 3 cm for molasses and 5 cm for massecuite, may be used. The apparatus is shown in Fig. 5B.

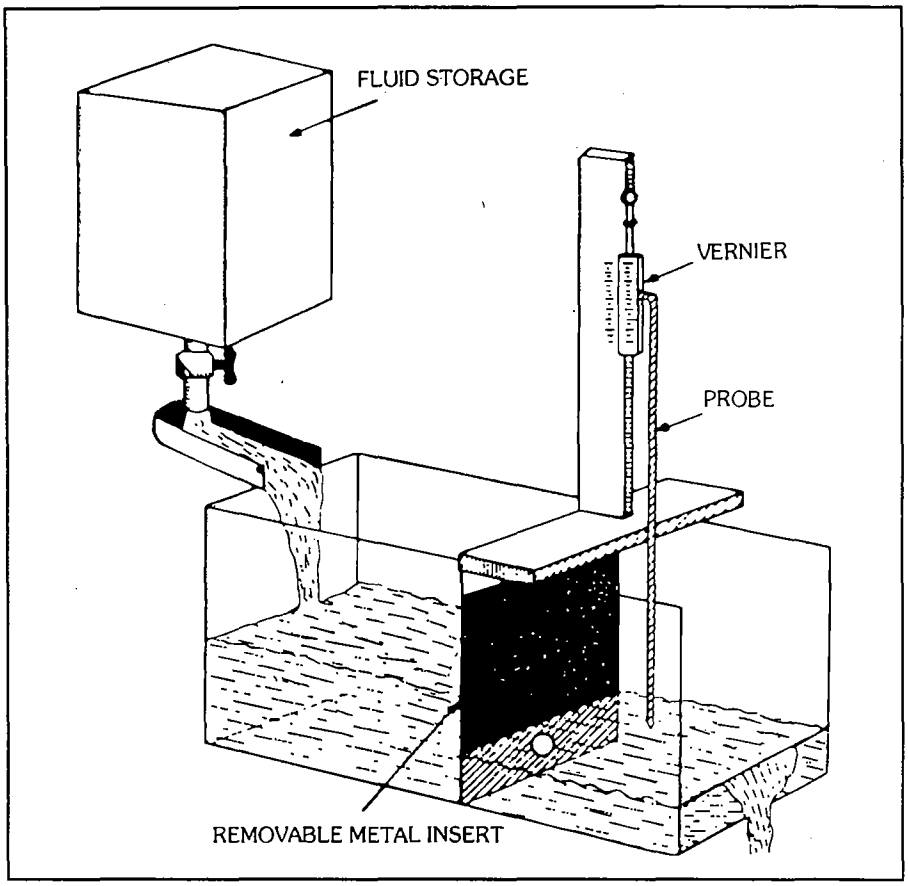

Fig. 5B : **Orifice Viscometer**

The viscosity (μ) in PaS at a particular temperature and shear rate is given by the equation :

$$La = \frac{\Delta h\, D}{V\mu}$$

Where D is the orifice dia Δ h the head loss across the orifice, V the velocity through the orifice and μ the apparent viscosity in PaS. The value of La (Lagrange number) has been found to be 19.00.

Shear rate $\alpha = \frac{8V}{D}$ where V is velocity of flow and D, the diameter.

The method is particularly suitable for flow measurements.

(Ref. : S.M.R. Maudarbocus, Mauritius Sugar Industry Research Institute, Proc. ISSCT, 1980 pages 2257-2263).

Note : 1 m PaS = 1 centipoise)

Both the above methods are applicable to massecuites also.

5.2.8 **Ash:**

Take 10 g of the molasses dilute the sample 1:1 to make it homogeneous. Then transfer the solution into a weighed 100 ml. platinum dish, add about

10 ml. of concentrated sulphuric acid (1.84 g/ml..), heat on a plate with low heat when it chars and swells considerably. Then heat the mass carefully. After all the sulphur-trioxide and sulphur dioxide fumes have escaped, further heat the dish over a direct flame or in a muffle furnace maintained at 550°C - 600°C, for 2 hours till a pinkish grey ash results. After cooling moisten the ash again with a few drops of sulphuric acid and reheat at 650°C for 30 minutes to drive off the excess of sulphuric acid. Then cool the dish in a desiccator to room temperature and weigh.

$$\text{Sulphated ash \%} = \frac{\text{Weight of ash} \times 100}{\text{Wt. of sample}}$$

6. **Magma:**

Sampling:

Magma should be sampled from magma–mixers after thorough mixing has been achieved.

Preservative:

Not necessary.

Analysis:

The procedures for determining Brix and Pol are the same as given for massecuite.

7. **Bagasse:**

Sampling:

Bagasse should be sampled from the entire breadth and depth of the bagasse carrier, once, in four hours. About 10 kg thus sampled should be subsampled immediately to 2 kg and sent to the laboratory for immediate analysis in a convered sample can. Last expressed juice should be simultaneously sampled and sent to the laboratory for analysis, once, in four hours.

Analysis:

Analyse for moisture and pol.

7.1 **Moisture:**

Take 100 g of the sample in a weighed tray or basket, perforated on all sides. Dry in a suitable oven maintained at about 110°C. Carry out the drying to constant weight. The loss in weight gives moisture per cent bagasse. When the Java type bagasse drier is used 500 g of the sample are weighed in place of 100 g.

7.2 **Pol:**

(a) *Noel Deerr Method:*

The Deerr digester is made in two sizes for approximately 500 g or 1000 g of bagasse. One for 1000 g of bagasse is preferred. The exact quantity of

water is fixed by the level of the upper cock on the side of the vessel. The capacity of the digester is determined by filling it with water until it overflows through the upper cock. Suppose it is 7215 ml. and bagasse moisture is 46 per cent. The quantity of bagasse (B) to be taken to furnish a half normal (13 gms per 100 ml.) solution is found from the equation:

$$B = \frac{(7215 + 0.46\ B)}{100/13}$$

or $7.69\ B = 7215 + 0.46\ B$

or $7.23\ B = 7215$ or $B = \frac{7215}{7.23} = 998$ gms.

The digester is filled with water containing a little sodium carbonate upto the level of the upper cock. The basket and its load of bagasse are then dropped in, the lid and reflux condenser placed in position and the whole put to boil for one hour after boiling has started. After one hour, the digester and its contents are allowed to cool to about 95°C the lid and condenser removed and the contents well mixed by moving the basket up and down by the handle. After mixing, the required quantity of the extract is drawn off into a Jena or pyrex flask and cooled to room temperature. Two hundred milliliters of this extract is treated with Horne's dry lead acetate, filtered and polarized in a 400 mm pol tube. With the dimensions and volumes and weights chosen according to calibration, the original aqueous extract is a half-normal solution, so that, when using 400 mm tube the reading directly gives the polarization of the bagasse.

(b) *Rapi-Pol Extractor Method:*

Rapi-pol Extractor is a mixer-cum-disintegrator developed for the quick determination of Pol per cent bagasse, or pol per cent cane or fibre per cent cane. It consists of mixing-cum-disintegrating blades fixed to the shaft and a stainless steel vessel for holding the samples. The unit is driven through V belt and pulley by a 1.5 HP motor with a time switch and starter.

Procedure for determination of Pol per cent bagasse:

(a) 250 gms of uniformly mixed sample of bagasse is taken in the stainless steel vessel.

(b) 2000 ml. of water (at room temperature) is added.

(c) The vessel is fixed to the bearing bracket.

(d) The timer is set for 5, 7 or 10* minutes and the motor started.

---

* Determine the exact time by a few trials. The time should be enough for complete extraction of Pol.

(e) After 5 to 10 minutes rotation the vessel is taken out and the liquid decanted.

(f) Sufficient amount of lead sub-acetate is added and the liquid is filtered.

(g) The filtrate is to be polarized in a 400 mm tube.

(h) This direct pol reading is multiplied by corresponding moisture per cent factor given in the Table below which gives the pol per cent of the sample under test.

Table for Moisture Factor

Table No. 3

Moisture %	Multiplying factor	Moisture %	Multiplying factor
4.2.5	1.100	62.5	1.132
45.0	1.104	65.0	1.136
47.5	1.108	67.5	1.140
50.0	1.112	70.0	1.144
52.5	1.116	72.5	1.148
55.0	1.120	75.0	1.152
57.5	1.124	77.5	1.156
60.0	1.128	80.0	1.160

8. **Filter Cake:**

Sampling:

A representative sample may be selected from the cake van by pushing an old evaporator tube through the depth of the cake as it goes for weighing. There should not be much time lapse between dropping the cake and sampling. Where total weight of cake is calculated from the weight of cake of one chamber the sample for analysis should be drawn from the middle and two end chambers by means of a pipe piece from five places in each chamber *i.e.*, the four corners and center. The analysis should be done once in four hours.

Analysis:

8.1 **Moisture:**

Spread 100 g of the composite sample in a thick layer in a weighed shallow tray with a perforated bottom and dry to constant weight at about 110^{0}C. The loss in weight gives the moisture per cent filter cake.

8.2 **Pol :**

In the case of a Sulphitation factory, triturate 25 g of the sample in a mortar to smooth paste with hot water. Transfer to a 100 ml. flask, cool and complete the

volume. Add 1 to 2 g of Horne's dry lead, shake, filter and polarize in a 200 mm tube. The reading directly gives the pol per cent filter cake.

In the case of a carbonation factory triturate 50 g of the cake with 15 g of ammonium nitrate water, transfer to a 200 ml. flask, make up to volume, clarify with Horne's dry lead, filter and Polarise as above. The reading of the polariscope directly gives the pol per cent filter cake.

8.3 Bagacillo content of Settlings or Filter Cake :

Use either IS : 18 test sieve or Tyler 80 mesh or equally fine laboratory screen. Weigh out 250 g of settlings or filter cake. Place about one quarter of this on the screen and wash under a faucet. The bagacillo will remain on the screen while the fine dirt particles will be washed through. When most of the dirt has been washed away, add more of the settlings and wash in the same manner. Continue until the whole 250 g have been transferred to the screen. Watch the colour of the water leaving the screen and continue washing three minutes after the water becomes clear. Remove, by using a camel hair brush, the washed bagacillo from the screen to a watch glass and dry in the oven. The weight of the dried bagacillo divided by 2.5 will give the percentage of bagacillo in the settlings or filter cake. (See Figure 6A)

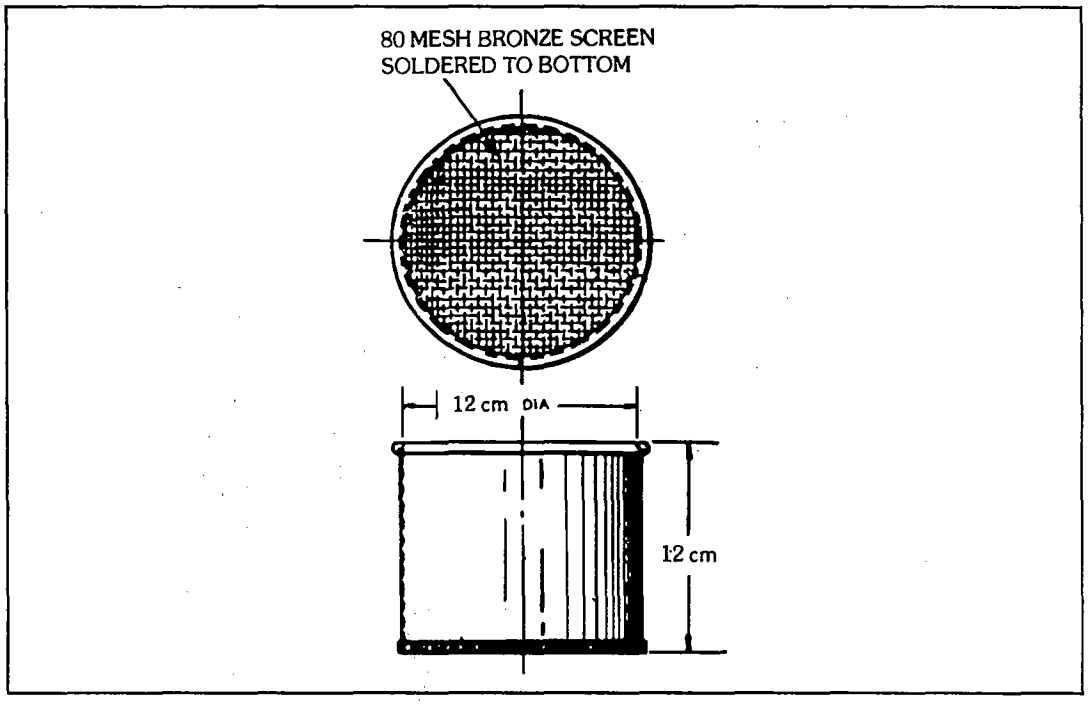

Fig. 6A : Screen for determining bagacillo content

Bagacillo contents of settling

8.4 Retention in rotary Vac. filter (R) :

$$R = 100 - \frac{\text{Mud solids \% filtrates}}{\text{Mud solids \% filter - feed}} \times \frac{\text{Brix \% filter - feed}}{\text{Brix \% filtrates}} \times 100$$

Analysis :

The following analysis are to be carried out :

(a) Insoluble solids in filtrates

(b) Insoluble solids in filter-feed

(c) Brix per cent filtrate

(d) Brix per cent filter-feed

Determination of Insoluble Solids :

(i) The filtrates are collected from the delivery pipes of filtrate-pumps at the point of discharge into the raw-juice receiving tank and samples from both the filtrates are mixed in equal proportion, for analysis.

To 100 g of the sample, add 1.0 per cent solution of Separan AP 30 or any flocculating agent to bring about good floc formation. The solutions is then filtered under vacuum in a Buchner funnel through a double set of smugly fitting filter papers. Alternatively a funnel may be constructed as shown in the Figure. The residue is washed to ensure removal of juice. Continue filtration until all wash water has passed through the cake and drying cracks appear on the cake surface. Then shut off vacuum, remove the funnel from the flask, invert it and blow through the narrow end to discharge the cake together with the filter papers. Strip the papers from the cake and dry the cake on a watch glass in a drying oven at 96 - 100^{0}C to constant weight. The dry cake weight gives the per cent insoluble solids in the test sample.

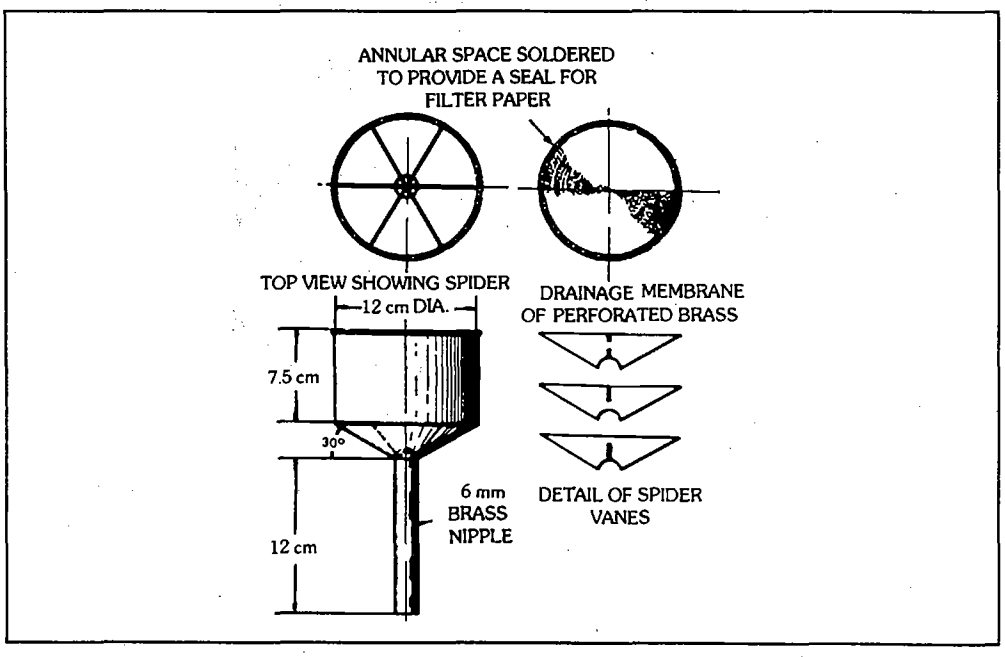

Fig. 6B : **Vacuum funnel for determining insoluble solids**

(ii) 100 g of filter feed is strained through 100 mesh wirecloth to remove the fibre and treated with Separan AP 30. The liquid is filtered in Buchner funnel under vacuum. The same procedure is followed as under (i) above but the residue after washing is dried at 100 - 105^0 C and weighted to constant weight.

(iii) The filtrate sample is treated with Separan AP 30 and filtered. Clear filtrate is analysed for brix. Brix of the filter feed is found by similar procedure.

(Reference : D.P. Kulkarni & M.R. Shinde, DSTA proc. 21 Conv. 1956). There is another method based on the formula.

$$R = \frac{Mc}{Fc} \div \frac{Mf}{Ff} X100, \text{ where;}$$

Mf and Mc and Ff and Fc are mud solids per cent and bagacillo contents in Feed and Cake respectively.

Followed in Queensland but it is rather too elaborate. See Lab Manual For Queensland Sugar Industry.

9. White Sugar :*

9.1 Moisture (Loss on drying)

* Essential requirements for Plantation White Sugar

Moisture % Max	Pol % Min	Reducing Sugars % max	Sp. Con. ductivity 10^6t Max	SO_2 ppm Max	CaOmg/ 100g Max	Turbidity %by wt Max	Water insolubles by wt. Max
0.08	99.5	0.10	100	70	30	15	0.10

(See IS 5982-1970)

Sampling :

About 10 g sample should be taken from each bag of sugar and composited for the day. The different grades of sugar should be separately composited to facilitate analysis.

Analysis :

(BNC Method) Carry out the determination in duplicate. Take 20 g sugar in a previously dried and tared polished aluminium metal dish 6.0 cm diameter and 2.5 cm height with close fitting lid provided with a knob. Empty dishes should be dried in the oven with lids open for not less than 30 minutes. After replacing the lids, cool the dishes in the desiccator with contact thermometer and containing self-indicating silica gel. Weigh the dishes when temperature has fallen to ambient + 5^{0}C to an accuracy of ± 1.0 mg. Spread this sugar in an even layer. The depth of sugar must not exceed 1.0 cm.

Cover the dish immediately and weigh it accurately in an analytical balance to an accuracy of ± 0.1 mg. Remove the covers and place the dishes in an electric oven

and dry the material for 3 hours at $105^0 \pm 1^0$C. The thermostat should be set for this temperature. There should not be any other material in the oven. The oven should be forced draught atmospheric pressure ventilated oven, preheated to $105^0 \pm 1^0$C as measured 2.5 cm above the dishes. Remove the dishes from the oven, cover them, cool in a desiccator to ambient temperature $+5^0$C and weigh to an accuracy of ± 0.1 mg.

Calculate loss in weight as percentage of original weight.

9.2 **Pol :**

Reagent :

Preparation of Alumina Cream : To a cold saturated solution of potash alum [K Al $(SO_4)_2.12H_2O$], add ammonium hydroxide with constant stirring until the solution is alkaline to litmus. Wash the precipitate by decantation almost free of sulphate. Then pour out excess water and store the creamy suspension in a stoppered bottle.

Procedure for analysis :

Dissolve 26 g in about 80 ml. of water in a 100 ml. measuring flask. In the case of white sugar, add 1 to 2 ml. of Alumina cream and in the case of brown sugars add 0.2 to 0.6 g dry lead subacetate. Then mix the contents thoroughly and make the volume upto 100 ml., shake well and filter. Reject the first 25 ml. of the filtrate. Polarise the remainder filtrate in a 200 mm tube. The reading obtained gives directly the pol per cent sugar.

If the polarisation is carried at a temperature other than 20^0C, the saccharimeter reading should be corrected using the following formula.

$$S_{20} = S_t [1 + 0.0003 (t - 20)]$$

Where

S_{20} = Saccharimeter reading at 20^0C

S_t = Saccharimeter reading at t^0C

t = Temperature in degrees centigrade at which the polarisation is carried out.

(Note : The formula is applicable only upto 30^0C)

9.3 **Sucrose :**

For determining sucrose, use the double polarisation method of Jackson and Gillis (Method IV). In this method neutral salts are used in the direct polarisation to offset the effect of the acid on the invert sugar in the invert polarisation.

Preparation of samples :

Weigh accurately 52 g of sugar in a basin. Transfer this quantity to a 200 ml. volumetric flask with the aid of a long stemmed funnel. Rinse the basin and the

funnel with water and transfer the washings to the volumetric flask taking care that the volume in the flask does not exceed 160 ml.. Bring the sugar into solution by gently swirling the flask and make up the volume to 20 ml.. Clarity the solution by adding minimum quantity of dry lead subacetate. Filter the solution and add dry potassium oxalate or sodium oxalate to the extent that the filtrate gives no further precipitation and filter. Then determine 'direct' and 'invert' polarisation.

Procedure for direct polarisation :

Same as given for mixed juice.

Procedure for invert polarisation :

Same as given for mixed juice.

Calculations :

Same as given under mixed juice.

9.4 **Reducing Sugars :**

This may be determined by the Ofner method given below :

Scope and field of application :

The method is used for the determination of invert sugar in products with an invert sugar content upto 10 per cent in the presence of sucrose. Because of the small sucrose correction the method is especially suitable for the determination of invert sugar in mixtures containing large amounts of sucrose.

Apparatus :

Erlenmeyer flasks, 300 ml. capacity.

Burette stand equipped with two 50 ml. burettes with 0.1 ml. graduations.

Reagents :

(i) Ofner's solution :

Cupric sulphate pentahydrate (5.0 g), anhydrous sodium carbonate (10.0 g), pulverised sodium potassium tartrate tetrahydrate (300 g) and di-sodium hydrogen orthophosphate dodecahydrate (50 g) are transferred to a 1000 ml. volumetric flask and dissolved in distilled water, with shaking at room temperature, to a total volume of about 900 ml., if necessary, the mixture may be warmed in a water-bath to assist solution. After solution is complete, the mixture is heated in a boiling water-bath for 2 hrs to destroy mould spores; it is then cooled, made upto the mark, and filtered through fine porosity sintered glass or with kieselguhr or active carbon. The final solution should contain 126.8 mg Cu/100 ml.

(ii) Iodine solution, (0.032 N) :

Iodine (2.050 g) is dissolved in about 10 g of potassium iodide (iodate-free) dissolved in a few ml. of water. The solution is diluted to 500 ml. in a volumetric flask and is kept in a dark bottle with a well-fitting glass stopper.

(iii) Sodium thiosulphate, stock solution :

Sodium thiosulphate pentahydrate (20 g) and either sodium carbonate (0.1) g or N sodium hydroxide solution. (1 ml.) are dissolved and made upto the mark in a 500 ml. volumetric flask.

(iv) Sodium thiosulphate solution, (0.0323 N) :

This solution is made up as required by diluting the sodium thiosulphate stock solution (100 ml.) to 500 ml. in a volumetric flask. The reagent is standardised with iodate.

(v) Starch indicator solution :

Soluble starch (2.5 g) and mercuric iodide (about 10 mg) are rubbed in a little water and dissolved in about 500 ml. of boiling water.

Procedure :

A pipetted or weighed amount of the product, containing not more than 40 mg of invert sugar (e.g 20 g white sugar) is dissolved in distilled water and diluted to 100 ml. 50 ml. of this solution is transferred to an Erlenmeyer flask and 50 ml. of Ofner's solution added. After mixing pumice or talcum powder (50 to 100 mg) is added and the mixture heated to boiling in 4 to 5 min.

The initial time of boiling is judged not from when bubbles arise from the bottom of the flask, but when they break at the surface in considerable numbers. Boiling is continued for exactly 5 min. after which the mixture is cooled rapidly (without agitation) in running water.

Glacial acetic acid (1 ml.) is added and followed immediately, with continuous agitation by an excess of iodine solution (5 to 30 ml.). N hydrochloric acid (15 ml.) is then carefully poured from a graduated cylinder down the inner wall and mixed into the contents of the flask. The flask is immediately stoppered and the iodine allowed to react for 2 min with occasional agitation.

The excess of iodine is back-titrated, about 2.5 ml. of starch solution being added as indicator as the end-point is approached.

Corrections to be applied to iodine titre to obtain mg invert sugar

Table No. 4

0.032 N iodine solution ml.	Weight of Sucrose (g)									
	1	2	3	4	5	6	7	8	9	10
1	0.11	0.22	0.34	0.45	0.55	0.66	0.77	0.89	1.00	1.11
2	0.17	0.28	0.40	0.51	0.61	0.72	0.84	0.95	1.06	1.16
3	0.22	0.34	0.45	0.57	0.67	0.78	0.90	1.01	1.12	1.22
4	0.28	0.39	0.51	0.62	0.73	0.84	0.95	1.07	1.18	1.28
5	0.33	0.45	0.56	0.68	0.78	0.90	1.01	1.12	1.24	1.33
6	0.39	0.50	0.61	0.73	0.83	0.95	1.06	1.18	1.29	1.39

Table No. 4 *(Contd.)*

7	0.44	0.55	0.67	0.78	0.88	1.00	1.11	1.23	1.34	1.44
8	0.49	0.60	0.72	0.83	0.94	1.05	1.16	1.28	1.39	1.50
9	0.54	0.65	0.76	0.88	0.99	1.10	1.21	1.33	1.44	1.55
10	0.59	0.70	0.82	0.93	1.03	1.15	1.26	1.37	1.49	1.60
11	0.63	0.75	0.86	0.98	1.08	1.20	1.31	1.42	1.54	1.65
12	0.67	0.78	0.90	1.02	1.12	1.24	1.35	1.47	1.58	1.69
13	0.70	0.82	0.93	1.05	1.16	1.27	1.39	1.51	1.62	1.72
14	0.74	0.85	0.97	1.09	1.19	1.31	1.42	1.54	1.65	1.76
15	0.77	0.88	1.00	1.12	1.22	1.34	1.45	1.57	1.69	1.79
16	0.80	0.91	1.03	1.15	1.25	1.37	1.48	1.60	1.72	1.82
17	0.82	0.94	1.05	1.18	1.28	1.40	1.51	1.63	1.74	1.85
18	0.84	0.96	1.08	1.20	1.30	1.42	1.54	1.66	1.77	1.88
19	0.86	0.98	1.10	1.22	1.32	1.45	1.56	1.68	1.79	1.90
20	0.88	1.00	1.11	1.24	1.34	1.46	1.58	1.70	1.81	1.92
21	0.89	1.01	1.13	1.25	1.35	1.48	1.59	1.71	1.83	1.94
22	0.86	0.98	1.11	1.23	1.34	1.47	1.59	1.71	1.84	1.95

Result :

The difference between the volume of iodine solution added and the volume of thiosulphate solution used in the back-titration is the volume of iodine solution consumed in the reaction. This value is corrected for the reducing effect of the sucrose present by subtracing a correction (see table) which depends on the volume of iodine solution consumed and on the amount of sucrose present. When this correction has been made 1 ml. 0.0323N iodine solution is equivalent to 1 mg of invert sugar.

9.5 **Ash :**

(a) *Ash (Sulphated) :*

In order to determine the suphated ash of superior white sugar, 10 - 35 g are weighed out into a previously heated, cooled and weighed platinum dish of about 9 cm in diameter. Weigh the dish with the sample. Weighments should be made in an analytical balance.

Then add 8 ml. of conc. sulphuric acid (1.84 g/ml.) to the sugar in the dish drop-wise while gently swirling the contents of the dish over a hot plate to assist mixing. Start the hot plate on low heat and gradually, increase to high heat to prevent spattering of the sample when the sample has been carbonized, transfer the dish to an electric muffle furnace and heat to a temperature 550^{0}C for 2 hours. In order to oxidise the ash to sulphate, remove from the furnace and cool and moisten it with a few drops to conc. sulphuric acid and heat again in a muffle furnace to a temperature of 650^{0}C for 30 minutes or till constant weight. After cooling in a desiccator determine accurately the weight of the dish again.

$$\text{The sulphated ash \%} = \frac{\text{Wt of ash}}{\text{Wt. of sample}} \times 100$$

(b) *Ash (Conductivity) :*

Analysis of ash in sugar products by the electometric method is based on the fact that distilled water is an exceedingly poor conductor of electricity as also is a highly purified solution of sugar. Soluble inorganic impurities as well as organic salts break up in water into ions which conduct electricity. Since the conductivity depends on the relative amounts of ions present in the solution it provides a method for determining the soluble ash.

Resistance is the inverse of conductivity and it is the resistance of the test solution which is actually measured. The result obtained can be correlated with sulphated ash by means of a suitable equation.

Specific conductively is measured in micromhos or microsiemens denoted by the symbol μs/cm.

Apparatus :

The specific conductivity may be measured by an instrument called 'Ash Bridge' or 'Conductivity bridge' which consists of the following components as shown diagrammatically in Figure No. 7 given below :

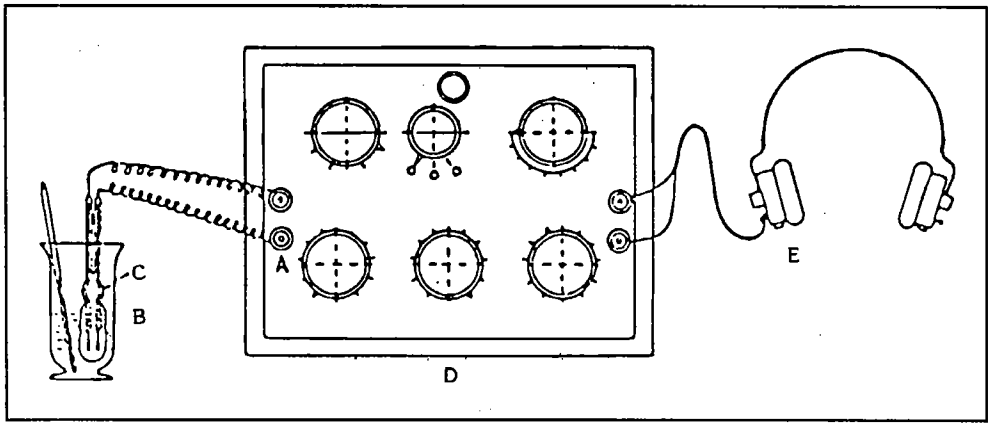

Fig. 7 : **Conductivity Bridge**

A. is a cell of which the constant is to be determined by preliminary standardization.

B. is the conductivity cell filled with the material whose resistance or conductivity is to be found.

C. is a pair of electrodes.

D. is the resistance box in which resistance can be altered.

E is a head phone or galvanometer.

Sophisticated readymade instruments are available, any one of which can be used according to instructions given.

Analysis :

Sample : For white sugar make a 28 brix solution (28g /100g) or take 31.3 ± 0.1 g of sugar in a vol. flask of 100 ml. capacity and make up to mark with conductivity water at 20°C.

Procedure :

(a) Determination of cell constant

Take 745 .5 g of potassium chloride (KCl) heat to about 500°C to dehydrate it, cool and then dissolve in 1000 ml. of conductivity water to give 0.01 N solution of KCl. Set the resistance dial to the theoretical resistance of standard KCl (0.01 N) and turn the temperature compensating dial to the temperature corresponding to the thermometer reading. Then switch on the current (A.C.) and adjust the cell-constant dial until the system is in equalibrium as shown by the galvanometer. The value thus found is the 'Cell Constant'. Lock the dial at this setting so that the instrument reads in true reciprocal ohms or mhos at any subsequent setting. Then pour the sample solution into the cell after several rinsings. With the cell constant dial locked in the proper position, the temperature adjusting dial is turned to the temperature indicated. (Temp. should be 20°C ± 0.2°C). Now turn the resistance dial until zero deflection on the galvanometer. The instrument now reads the specific conductivity of the solution in micromhos.

If C_1(µs/cm) is the measured conductivity at 20°C and C_2 is the specific conductivity of water at 20°C then corrected conductivity (C_{28}) of the solution is

$C_{28} = C_1 - 0.35C_2$ and conductivity ash percent

by weight $= 6 \times 10^{-4} \times C_{28}$

Note : (i) For all measurements, water with a conductivity lower than 2µs/cm shall be used.

(ii) If the determination cannot be made at 20°C a temperature correction may be made to the final result as follows. A correction of 2.6 per cent per degree C to be added for temperature below 20°C and subtraced for temperature above 20°C (upto ± 5°C).

Preparation of conductivity water :

Water available in the laboratory has to be first distilled over alkaline potassium permanganate in a conventional still after which it is redistilled in a Pyrex flask using a black-tin condenser. The first third portion of this distillate is discarded and the remaining portion is stored in a Pyrex glass container protected from atmosphere by a tube of soda-lime. The specific conductivity should not be more than 1.2–1.4 x 10^{-6} mhos. Conductivity water can also be prepared using ion-exchange method.

9.6 Grading of White Sugar*

In India plantation white crystal sugar is produced for home consumption. For marketing purposes its quality is judged in terms of its colour in solid state and grain size.

The visual colour in solid state of the whitest sugar produced is arbitrarily denoted as colour 31, the sugar which is a little less white is graded as No. 30 and sugar comparatively inferior to those is graded as No. 29. For grain size there are four categories: Large (L), Medium (M), Small (S) and Super Small (SS). The information regarding crystal sizes of L, M, S and SS grades is as given in Table No. 5.

Indian Sugar Standards :

Accordingly nine physical standards L-31, L-30, M-31, M-30, M-29, S-31, S-30, S-29 and SS-31 are prepared by the National Sugar Institute, Kanpur every year in square colourless sealed glass bottles and issued to the industry in wooden boxes. Sugar produced by every factory has to be visually matched against these standards, called Indian Sugar Standards and the quality so determined has to be marked on the jute bags in which it is packed.

The Indian Sugar Standards have to be produced every year because the colour of the sugar in the standard bottles goes down on keeping. While preparing the standards, every year, the colour of fresh standards in all the three standard grain sizes is so chosen as to have same standard reflectance and M.R. value as in the previous year's standard bottle. The reproduction of the same colour is ensured by measuring the colour of the sugar to be filled in the bottle with the help of a Photoelectric Reflectometer. Sugars showing the same M.R. values (modulated reflectance value) as in the previous year are chosen.

The method of determining M.R. value is given in para (4) below :

Method of determining the grade of sugar :

The bagging of sugar in a sugar factory is continuous, while the weighing and stitching of bags may be continuous or confined to the day time only. The screens of the sugar grader are fixed according to the specifications of grain sizes given later under. "Sieve test for determining grain size group of crystal sugar".

Care is taken to periodically inspect the screen for checking damage. The sugar issuing from the different chutes of the grader is bagged and kept separately. The sugar produced in each shift from different chutes is isolated by any convenient method. Sugar is then sampled from the bags of different chutes every hour by an aluminium or tin spoon into a small container and well mixed. Samples from each chute thus collected are graded by the Chemist-in-charge who should direct the stacking of bags according to his grading. In case the colour of the sugar of the different lost varies, those lost are kept separately and marked accordingly. The weighing is generally done after this preliminary grading. As each bag is weighed,

* From National Sugar Institute, Kanpur.

a sample from it should be taken by an aluminium or metallic spoon and emptied into a sample bucket corresponding to the rough grading. The number of sample buckets correspond to the number of grades anticipated. The sample buckets should be covered.

After the bags of one batch have been weighed and closed, the corresponding samples in the bucket should be graded according to the procedure given below and the bags marked accordingly.

(Note : The tests for the determination of grade shall be carried out by visual comparison of the sample under examination with sealed standard samples prepared and supplied by the National Sugar Institute, Kanpur).

Visual comparison shall be made in diffused day-light and not in direct sun light. In the absence of natural illumination, white artificial light produced by day-light bulbs and diffused by means of frosted glass, may be used.

Place all the bottles of the sealed standard samples in separate grain size groups, on a large sheet of white paper. In each grain size group, arrange the two standard colour grade bottles in descending order of colour.

Fill, upto the brim, the empty, square, colourless glass bottle supplied with the Indian Sugar Standard Box, with the composite sample of sugar under examination. Then tap the bottle gently over a hard rubber or wooden pad. The sugar will settle down. Fill up again with sugar leaving about 3 mm gap. Then insert the cork and press it tightly leaving no gap or void space between the cork and the sugar surface. Then place the bottle alongside the sealed standard bottle and determine by visual comparison the grain size group with which the sample under examination matches exactly.

Then similarly find out, again by visual comparison, the sealed standard for colour, in that particular grain size group, to which the sample under examination, exactly corresponds.

The grade of the standard sealed sample to which the sugar under examination most closely corresponds shall be the grade of the sample under examination.

In case grain size or colour or both of the sugar under test do not match properly with any of the standard sealed samples, one of the following situations may arise :

(a) The matching may be obtained in respect of grain size but not in respect of colour.

(b) The colour may match, but not the grain size.

(c) Neither the grain size nor the colour may match.

The sample under examination would in such a situation, fall between either two grain sizes or two colours of both. In all such cases the grade of the sample shall be that of the grade of the next lower sealed standard.

To illustrate : if the grain size is bigger than group M but smaller than L, and if the colour is better than that of 29 but inferior to 30, the grade for sugar under examination shall be M 29.

Crystal sugar which is below the specific requirement either in respect of grain size or colour shall be designated as "Below ISS Grade".

Sieve test for determining grain size group of crystal sugar :

When visual comparison of grain size group is considered inadequate, the grain size group shall be determined by this method.

Sieves to be used for this test shall be 20 cm in diameter. They shall preferably be Indian Standard Test Sieves, but in the absence of these, the equivalent Tyler Test sieves may be used.

Determine approximately by visual comparison the highest grain size group in which the sample of sugar under examination is likely to fall. Select three sieves

Requirement for Grain Size Groups of Crystal Sugar

(For 2004-05 Season)

Table No. 5

Grade	IS Sieve	Tyler Sieve	Percent Retained by Mass (Min)	Standard M.R. Value	ICUMSA Value (For Season 2004-05)
L-31	1.70 mm	10	70	94	Around 125
L-30	850 micron	20	95	82	Around 185
	600 micron	28	99		
M-31	1.10 mm	14	70	68	Around 76
M-30	600 micron	28	95	60	Around 119
M-29	425 micron	35	99	52	Around 205
S-31	600 Micron	28	70	40	Around 60
S-30	300 Micron	48	95	37	Around 105
S-29	212 Micron	65	99	34	Around 127
SS-31	212 Micron	65	70	14.5	Around 60
	175 Micron	80	95		
	147 Micron	100	99		

Note :

(1) Though ICUMSA colour unit is no way interrelated with colour in solid phase *i.e.* in terms of modulated reflectance, but these values as shown against each grain size in the last column is only in approximation and should not be considered at par with colour value in solid phase.

(2) If the sample under examination is found below grain size group SS, the sugar shall be considered as "Below ISS Grade".

corresponding to that grade (see Table given below) and nest them together in descending order of mesh size, with the coarsest sieve at the top and with the receptacle at the bottom. Weigh accurately 100 g of sugar out of the composite sample of sugar under examination and transfer this quantity on the top sieve. Cover the top sieve with a tight fitting lid, place the nest of sieves and the receptacle in a suitable mechanically driven sieve shaker and shake it continuously for five minutes. Brush the fractions of sugar from each sieve separately into weighing dishes and weigh the fractions accurately. The weight of each fraction in grams shall be the percentage of sugar retained on different sieves from which cumulative percentage may be calculated and compared with figures given in column 4 of Table No. 5 for the corresponding group. If the figures do not comply with the limits prescribed for the grade in the Table, repeat the above process of sieving by using a fresh quantity of 100 gm of composite sample and another set of three sieves of a lower or higher grade as the need be. The grain size group thus determined shall be the grain size of the sample under examination. However, grading is to be done one the basis of visual comparison as prescribed in IS 498-1970.

Methods of determining MR value :

The photo-electric Reflectancemeter as specified in (IS-7424-1974) is connected to AC mains. The voltage is maintained at 230 volts by a voltage stabilizers, alternatively, a 6 or 8 volt storage battery may be used. The lamp voltage is adjusted to the specific value and the galvanometer is also adjusted to zero with the help of the knob meant for the purpose. Put the green filter (colour correcting filter) in the search unit and place it on the polished black glass plate. The meter should then indicate zero reflectance, if not, adjust the zero control to set the meter to zero. Then place the search unit on the standard white plaque and adjust the sensitivity control to get the correct reflectance reading for the calibrated plaque, that is, if the plaque is for 92.2 reflectance should be 92.2.

Now place the search unit on the gray enamel plaque and check that the meter gives the correct value of reflectance for the calibrated plaque. This is a check of the linearity of the meter scale. The plaque and the black plate should be washed with a neutral detergent or soft soap and dried before use. Care should be taken not to scratch their surfaces, especially, that of the black glass plate. After suitable interval, the reflectance values of the white and gray enamel plaques should be checked against magnesium oxide standard.

The sugar to be tested is sieved through standard sieves for 15 minutes and only that portion between the sieves is taken which conforms to its grain size. Then it is packed tightly in the square shaped bottle of colourless glass and corked. While filling the sugar, the bottle should be gently tapped. There should not be any empty space below the cork. The bottle is then placed on the search unit and the reflectance reading is taken on all the four sides of the bottle at several places and the mean value of all the reflectance readings is found out. Let this be R, then MR value is equal to R x G where G is the grain size of the sugar under test.

10. **Raw Sugar :**

Sampling :

(a) *At the time of bagging :*

A spoonful of sugar should be taken from each bag while it is being filled and collected in a container, the lid of which is fitted with a small funnel. The orifice of the funnel, should be small so as to avoid undue moisture variation. When the sampling is completed the funnel is, replaced by a close fitting lid.

(b) *From Consignments :*

A stainless steel trier should be used to collect sugar from every tenth bag to obtain the composite sample. The trier should be inserted into the bag in its middle position.

The sample so obtained from different bags should be mixed thoroughly and composited after subsampling if necessary. The top layer of the sugar sample in the container should be scraped off and discarded before analysis.

Analysis :

Raw sugar may be analysed for the following :

(a) Moisture

(b) Pol

(c) Reducing sugar

(d) Ash (sulphated and conductivity)

(e) Colour in solution

(f) Grain Size

(g) Starch

(h) Wax

(i) Filterability

The methods of analysis are as follows :

10.1 **Moisture :**

Take an aluminium flat dish of size 25 mm height x 60 mm diameter and having a close fitting cover and heat it with the cover at 105^{0}C for one hour, cool it and weigh. Transfer about 5 g of the raw sugar sample into the dish and spread the sugar evenly.

Cover the dish and weigh accurately and place it in an air oven removing the cover but leave it in the oven. Dry the sample at 105^{0}C in an air oven for 3 hours or in a vacuum oven at a temperature not exceeding 70^0 C under a pressure not exceeding 50 mm of Hg for 2 hours. In the latter case it should be redried and reweighed for

one hour periods until the change in weight in successive one hour intervals is not more than 2 mg. The oven should be bled with a current of dry air during the drying to ensure removal of water vapours. Then cool it in a desiccator and weight. The loss in weight, divided by the weight of sugar taken, multiplied by 100 is recorded as percentage moisture.

$$\text{Moisture\%} = \frac{\text{Loss in weight x 100}}{\text{Weight of raw sugar}}$$

Note : The analysis for moisture determination must be done in duplicate.

Safety Factor :

The Safety factor is calculated by the following formula :

$$\text{Safety factor} = \frac{\text{Moisture}}{\text{100 – Pol}}$$

10.2 **Polarisation**

Weigh in an analytical balance (accuracy ± 0.002 g). 26.00 g of sugar in a sugar scoop and dissolve the sugar in distilled water by stirring with a glass rod and then transfer the contents by washing with distilled water into a standard 100 ml. measuring flask to a volume not exceeding 70 ml. using a funnel. Mix the contents by washing with distilled water by agitating the flask by hand swirling or automatic shaker and make the volume to about 90 ml. Add from a burette 1.0-2.0 ml. of basic lead acetate solution (54.3 Bx containing 9.5 - 10.5 g of lead in basic form calculated as PbO/100 ml.). ICUMSA recommends only 0.1 ml., if necessary a little more may be added upto 2.0 ml. to ensure a clear filtrate. Mix the lead solution by swirling motion. Wash the sides of the flask and remove the air bubbles by rotating the flask and adding a drop of either to break the foam if any. Immerse the flask in a thermostat maintained at 20°C ± 1.0°C for at least ten minutes. Make up the volume exactly to the 100 ml. mark. Mix the contents of the flask thoroughly by shaking and inverting the flask at least three times. Place the flask again in the thermostat for 5 minutes to permit the settling of the precipitate. Pour the solution into a single filter paper placed in a funnel and cover it with a watch glass. Discard the first 10 ml. of the filtrate. Rinse the pol tube with filtrate 2-3 times and then fill it with the filtrate without entrapping any air bubble for taking the pol reading. Take the pol reading in a 200 mm pol tube which gives the pol of sugar.

(In case a thermostat is not available and it is not practicable to make the polarisation at 20°C, it should be made as near to 20° C as possible. No temperature correction is considered necessary from 18 - 22°C. For readings at other temperatures it is sufficiently accurate to add or subtract 0.03 pol for each increase or decrease of 1°C from the standard 20°C).

Net Rendement :

This gives a measure of the refined sugar obtainable from raw sugar and is evaluated by estimating pol, ash and reducing sugar. The formulae for estimation being empirical vary from country to country.

The formulae used in different countries are as given below :

France

Net Rendement : Pol – (4 x Ash + 2 x Reducing sugar)

Japan

Net Rendement : Pol – (4.5 x Ash + Reducing sugar)

Netherlands

Net Rendement : Pol – (5 x Ash + 3 x Reducing sugar)

10.3 **Reducing Sugars:**

Reducing sugar is determined by Lane and Eynon constant volume method as given under Final Molasses. The concentration of the test sugar solution should be so arranged that the invert sugar concentration lies between 250 and 400 mg/ml.

Thus weigh 40 g of raw sugar sample in a nickel crucible transfer this to a 400 ml. beaker and dissolve in about 100 ml. of water by stirring. Transfer the solution to a 200 ml. volumetric flask. Add 3 to 5 ml. of 10 per cent neutral lead acetate solution and about 10 ml. of deleading solution. Mix thoroughly and filter. Then follow the procedure as given under 'Final Molasses' for reducing sugar determination.

10.4 **Ash:**

(a) *Sulphated Ash:*

Weight 5 to 10 g of the sugar sample in a 100 ml. capacity platinum dish. Add 2 – 5 ml. of concentrated sulphuric acid (1.84 g/ml.) and heat the crucible gently on a hot plate or on a Bunsen burner, covering half the crucible with the lid till the sugar is completely charred. Then transfer the crucible to a muffle furnace and heat at 550°C for 2 hours until apparently free of carbon. Remove from the muffle and cool. Add again a few drops of concentrated sulphuric acid and reheat till dry; then place the crucible into the muffle furnace and reheat at 650°C for 30 minutes, then cool in a desiccator and weigh to ± 0.002 g.

$$\text{Sulphated ash} = \frac{\text{Weight of ash} \times 100}{\text{Weight of sugar}}$$

(b) *Conductivity Ash:*

The procedure is the same as for white sugar (9.5b) except that for raw sugar,

(i) Sample concentration is 5g/100 ml. (Conductivity C_5)

(ii) If C_1 is the measured conductivity at 20^0C, C_2 conductivity of water then $C_5 = C_1 - 0.9\ C_2$, and

(iii) Conductivity ash % by weight = $18 \times 10^{-4} C_5$

(iv) Temperature correction will be 2.3% per degree C upto $\pm 5^0$C.

Note : For juices, syrup and molasses, the sample concentration should be less than 5 g/100 ml. and as in the above method $C = C_1 - C_2$ where C_1 is the conductivity of the solution C_2 that of dilution water then

Conductivity as % by weight = $C \times (16.2 + 0.36\ D) \times 10^{-4}$

Where D = dry substance concentration of the solution in g/100 ml.

10.5 **Grain Size (Grist Test):**

Take 100 g of raw sugar and dry it preferably after washing with 100 ml. of anhydrous alcohol. The excess alcohol is removed by filtration. Dry the washed sugar in an air oven for about one hour. The temperature of the oven should be maintained at 80^0C in case it is washed with alcohol, otherwise at 105^0C. After cooling sift the sugar in standard sieves in an automatic shaker such as Ro-tap for 5 minutes. Find the weight retained on each of the standard sieves, which gives directly the percentage of sugar corresponding to different grain size limits.

(Note: For Contract No. 10, 28 mesh Tyler sieve is used).

10.6 **Starch:**

(Formamide method):

Dissolve 10 g of raw sugar in 10 ml. of distilled water in a 50 ml. centrifuge tube. Add 24 ml.. of alcohol (70 per cent V/V) and a few drops of saturated potassium chloride and after shaking vigorously keep the mixture overnight. Then centrifuge it at 2500 RPM for 15 minutes. Decant the clear supernatant liquid and extract the residue with 5 ml. of 50 per cent formamide solution for 50 minutes in a boiling water bath. Near the end of the extraction wash the sides of the tube with distilled water to wash down any adherent material. Make up the solution to 25 ml. mark in the centrifuge tube with distilled water and centrifuge again. Transfer the clear supernatant liquid in a volumetric flask of 25 ml. capacity. Add one ml. of M/200 iodine solution, 20 ml. of concentrated HCl and make up the contents of the flask to the mark by distilled water. Measure the blue colour developed at 680 nm in a photo electric colorimeter using 2 cm cell against blank. From the optical density readings, the results are interpolated from the standard curve to be obtained as described below.

Procedure for drawing standard curve for the estimation of starch:

Weigh 0.25 g of corn starch accurately and make into a thin paste with 2 ml. of distilled water in a small beaker. Then heat and mix with distilled water (50 ml.). Boil the mixture gently for 10 minutes and cool, transfer to a 100 ml. volumetric flask and make upto the mark with distilled water. Take 10 g of sucrose (A.R. Quality) in 10 centrifuge tubes of 50 ml. capacity. The first tube serves as blank

and to the rest 9 tubes add 0.2, 0.4, 0.8, 1.2, 1.6, 2.0, 2.4, 2.8 and 3.2 ml. of starch solution respectively. Add in the first tube which serves as a blank. 10 ml. of distilled water and to the rest 9 tubes, 9.8, 9.6, 9.2, 8.8, 8.4, 8.0, 7.6, 7.2 and 6.8 ml. of distilled water respectively. The starch content of the samples is then estimated by the procedure described above by measuring the intensity of blue colour at 680 nm in 2 cm cell. The optical density values are then plotted against the concentration of starch to obtain the standard curve.

10.7 **Wax:**

Dissolve 100 g of sugar in 100 ml. of water and then heat to near boiling and add 2 ml. of 10% Potash alum followed by 2 ml. saturated solution of potassium dihydrogen phosphate and 4 g of acid washed Kieselguhr. Allow the mixture to stand overnight, then filter it through a Whatman No. 1 filter paper precoated with one gram of Kieselguhr. After washing with water and drying at 100^0C, extract the paper and cake in a Soxhlet apparatus with chloroform for at least 4 hours. Distil and evaporate the chloroform or benzene. The weight of the residue multiplied by 10 gives the wax in g/Kg of sugar.

10.8 **Filterability:**

A number of methods have been developed for assessment of the filterability of sugars. Of these, the one used by the Danish Sugar Corporation is simple and is described below:

The principle of this method is to measure the time taken for filtration of a known volume of the sugar solution under constant vacuum. The apparatus employed is similar to Brieghel Muller filtration apparatus shown in Fig. No. 8. It consists of a pipe with union which supports a disc of filter paper with surface area of 2 Sq.cm. The filter is connected to a measuring tube of 2 ml. capacity combined with a small security vessel. A constant vacuum is established by two vessels filled with mercury. One of the vessels is fixed on the frame while the other one is alternately placed on the upper fixed hook and the lower adjustable hook.

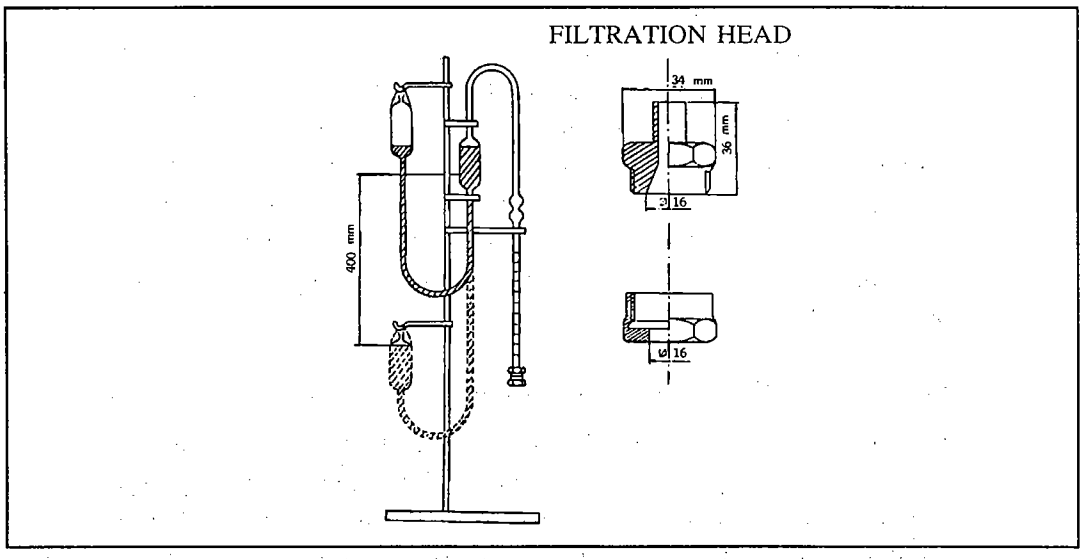

Fig. 8 : **Brieghel Muller filtration apparatus**

Prepare 40 per cent solution of raw sugar and pour the same in a beaker. Immerse the stirrer and the filter into this solution. Start the agitator and allow it to stir the solution at a constant speed. Lower the position of the mercury vessels from upper fixed hook to the lower adjustable hook. When a vacuum corresponding to 400 mm Hg is obtained, note by means of an accurate stop-watch the time required for the solution to rise in the measuring tube corresponding to a volume of 2 ml.. Repeat the experiment a number of times till a constant time value for filtration of 2 ml. of sugar solution is obtained.

Let t be the time (sec) required for filtration of 2 ml. of solution with the filtering area of 2 sq.cm.

Then coefficient of filtration is given by FK = 6.25 x t

Note : There are a few other methods in which a constant pressure is employed to effect filtration, using various types of filtering media. In some methods filterability of raw sugar solution is compared with that of a pure sugar solution under standard conditions then per cent filterability F is expressed as :

$$F = \frac{\text{Wt. of filtrate of test solution}}{\text{Wt of pure sugar syrup filtrate}} \times 100$$

(No method has however been officially approved by ICUMSA so far)

11. **Damaged Sugar:**

11.1 **Moisture**

As per procedure given for white sugar by using vacuum oven.

11.2 **Brix and Pol:**

Same procedure as given for massecuites.

11.3 **Sucrose:**

Find out sucrose in semi-normal solution by the same procedure as given for mixed juice.

11.4 **Reducing Sugars:**

By Ofner method as given for raw sugar.

11.5 **Ash:**

As per procedure given for raw sugar.

12. **Test for Sugar in:**

(i) Condensates (ii) Condenser water (iii) Boiler Feed water and (iv) Boiler water.

Presence of sugar in the above may be detected qualitatively by the Alpha-Naphthol Test described under Boiler Water Analysis, in Chapter VI Para 3.11.

CHAPTER – IV

SPECIAL ANALYSIS

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SPECIAL ANALYSIS

1. Determination of Preparation Index

Sampling :

Samples of cut cane should be drawn from the entire cross-section of the cane chute a little ahead of the knives and further sub-sampled by quartering.

Analysis :

Take the representative sample of prepared cane and divide it into two parts and treat the two parts as follows :

First Part :

(a) Weigh 500 gms of the prepared cane sample.

(b) Transfer the weighed sample into a jar used in ball mill (without porcelain balls) and add five litres of water.

(c) Mix the contents thoroughly by rotating the ball mill at 60/70 rpm for a pre-determined period*.

(d) Determine the pol reading of the extract. Note the reading as Pol_1.

* This period depends upon the ball mill specifications and the kind of preparatory devices used. Five minutes, after the start, a drop of liquid is drawn and refractometric brix taken with a hand refractometer. This is repeated for every minute until two concurrent readings are obtained. The time required in noted and is taken as the standard time for leaching.

Second Part :

(a) Weigh 1000 gms of prepared cane separately.

(b) Transfer the weighed prepared cane to wet disintegrator and add 3 litres of water.

(c) Run the wet disintegrator for about one hour** till constant brix of solution is obtained.

(d) Determine the pol reading of the extract. Note it as Pol_2.

** The time required is generally about 40 mts when the disintegrator blades are sharp but it increases as the blades become blunt.

Calculation :

$$\frac{Pol_1}{Pol_2} = r$$

$$\text{Preparation Index } K = \frac{1000\ r}{3.888 - 0.838\ r}$$

2. Determination of Mill Performance

For the evaluation of individual mill performance it is necessary to sample the bagasse from each unit. It is also necessary to determine the moisture content of each sample. Some technologists prefer to evaluate the pol or brix extraction of each unit which necessitates pol and brix determinations also. It is difficult to obtain a representative sample of bagasse, especially from the earlier mills of the train, where the bagasse contains larger particles. For this reason it is necessary to analyse a large number of samples and average the results.

It is suggested that each mill should be sampled at least once per shift and the results average over a week.

The performance of individual mills can be assessed by followed methods :

2.1 Plotting Brix Curves :

Curves plotted from the brix data of different mills have been used as a guide to judge the performance of individual mills in a milling train. In addition to the composite juice from each mill, some engineers prefer to take samples of juice separately from both the front rolls and the discharge rolls in which case three curves are plotted. It is essential that the sampling of juice from different mills is so timed that the same part of the blanket of bagasse is passing through successive rolls when the samples are taken and conditions during the entire test are as uniform and normal as possible.

The observed degrees of brixes of various mill juices are plotted against equal intervals on a graph paper. Side by side with the curve of observed brix values is plotted a curve for ideal brixes corresponding to the ratio of added water per cent cane (W) and fibre per cent cane (F). The ideal gravity solids, in terms of solids in the primary juice, are calculated using Deerr's formula for ideal cane viz.,

$$\text{Solids in secondary juice} = \frac{(1+S+S^2 \ldots + S^{n-1})}{(1+S+S^2 + \ldots S^n)}$$

$$\text{where } S = \frac{W}{F} = \frac{\text{added water \% cane}}{\text{fibre \% cane}}$$

and n = Number of secondary units

Example :

The added water per cent cane in a factory is 30. The fibre per cent cane is 15. Then $S = \frac{30}{15} = 2$ *i.e.*, $\frac{W}{F}$ ratio is 2.0. The factory has five mills in the train. The brix of primary juice is 20. Then the ideal brixes of juice in the secondary mills will be as follows :

Mill No. 2 : $(1 + S + S^2 + S^3) / (1 + S + S^2 + S^3 + S^4)$

or $(1 + 2 + 4 + 8) / (1 + 2 + 4 + 8 + 16)$

or $\frac{15}{31} = 0.484$

Mill No. 3 : $(1 + S + S^2) / (1 + S + S^2 + S^3 + S^4)$

or $(1 + 2 + 4) / 31 = \frac{7}{31} = 0.226$

Mill No. 4 : $\frac{3}{31} = 0.097$

Mill No. 5 : $\frac{1}{31} = 0.032$

As primary juice brix is 2, the ideal vales of brixes for Mill 2 to Mill 5 will be :

20 x .484 = 9.7

20 x .226 = 4.5

20 x .097 = 1.9

20 x .032 = 0.6

If the curve of observed values shows any kink or wide deviation from the ideal curve for any particular mill, it gives an indication that the performance of that particular mill is defective.

If the $\frac{W}{F}$ ratio is equal to 1.0, the curve will be a straight line.

If $\frac{W}{F}$ is greater than 1.0, the curve will be concave. If $\frac{W}{F}$ is less than 1.0 the curve will be convex in shape.

It may however be pointed out that conclusions regarding the working of a particular mill or mills should be drawn on the basis of a large number of brix curves obtained over a continuous period and not on a stray result as mill performance is dependent on a large number of variables. Moreover, the basis curve as derived above is based on the assumptions given below, which are seldom met :

(i) Cane consists of juice and fibre and both have uniform composition.

(ii) The bagasse delivered from each mill contains a constant proportion of fibre viz., 50 per cent.

(iii) Complete admixture of added water or returned dilute juice with the residual juice in bagasse.

By way of illustration, two charts are given in the following pages for a 15 roller milling plant. Chart I indicates the working of the plant with primary juice brix as 18.3 and W/F ratio of 1.89 for which ideal brixes can be calculated. A kink is noticed in the observed brix value of the 4th mill indicating that it was slightly loose. The feed side roll was tightened and brixes were taken again and graph plotted as in Chart II. The working showed an improvement. Bagasse pol came down from 3.5 to 3.4 per cent. (Charts I & II are on pages 81 and 82 respectively).

2.2 By Determining Moisture % Bagasse of Individual Mills

2.2.1 *Apparatus :*

Light duty balance

Hot air oven (Labotec, 105°C)

Moisture tray with gauze base

Pint brush (50 mm)

2.2.2 *Procedure :*

(a) Clean the moisture tray with the brush to remove all cane/bagasse particles and heat in the oven for 5 minutes.

(b) Zero the balance.

(c) Place the heated, clean, dry tray on the balance and record the "mass empty", M_1.

(d) Add 200 g of sample to the tray.

(e) Weigh the full tray and record the "tray plus bagasse" mass. M_2.

(f) Place the tray in the oven and dry at 105°C for 60 minutes.

(g) After the required drying time has elapsed, zero the balance.

(h) Weight the "tray plus dry sample" hot and record this as M^3. This step must be done rapidly to avoid errors due to the absorption of moisture by the hot dry sample. At the same time care must be taken that small particles of dry fibre are not blown away.

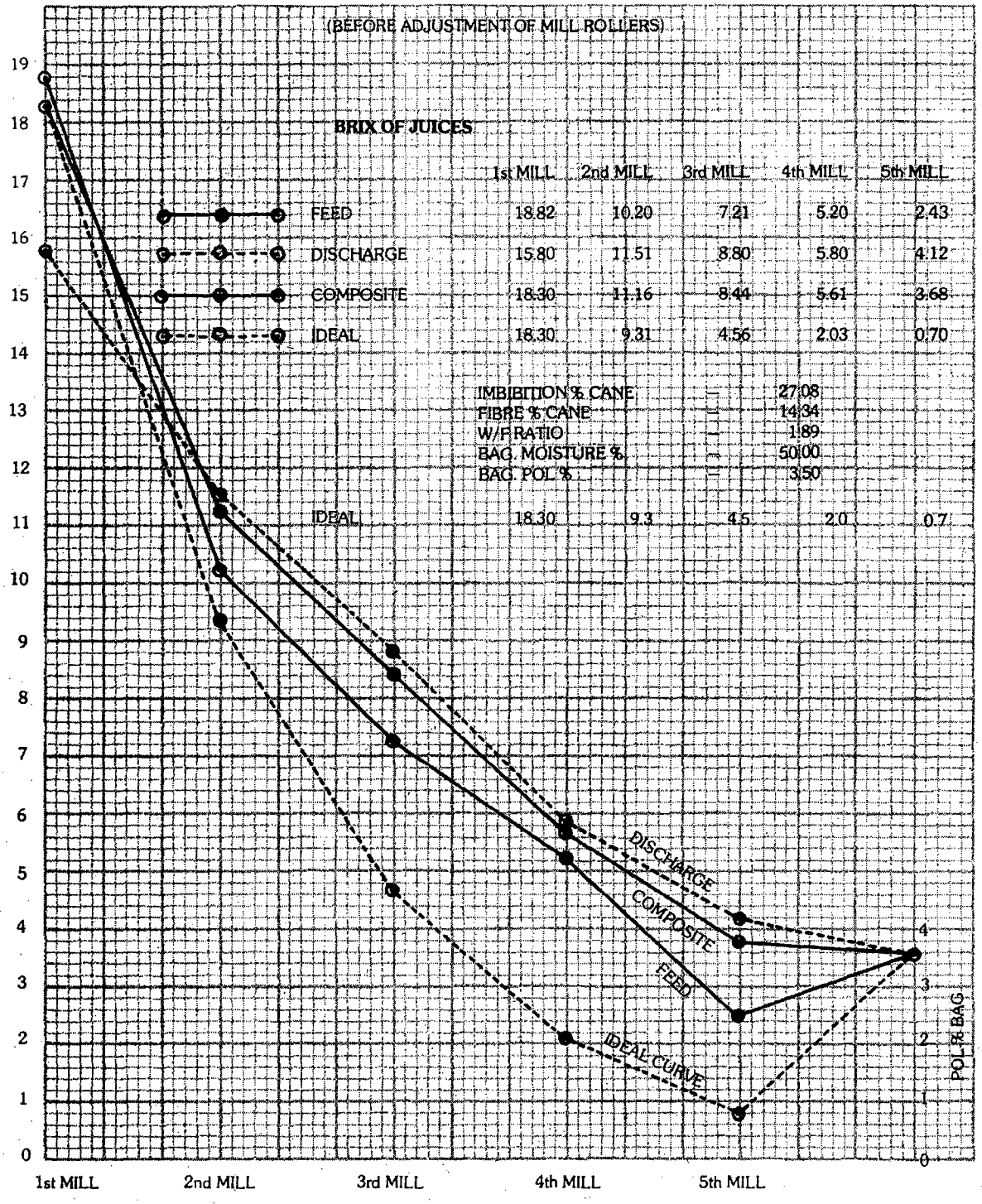
(i) Discard the dried sample and clean the tray by brushing.

2.2.3 *Example :*

$$\text{Moisture \% bagasse} = \frac{(M_2 - M_3)}{(M_2 - M_1)} \times 100$$

CHART I

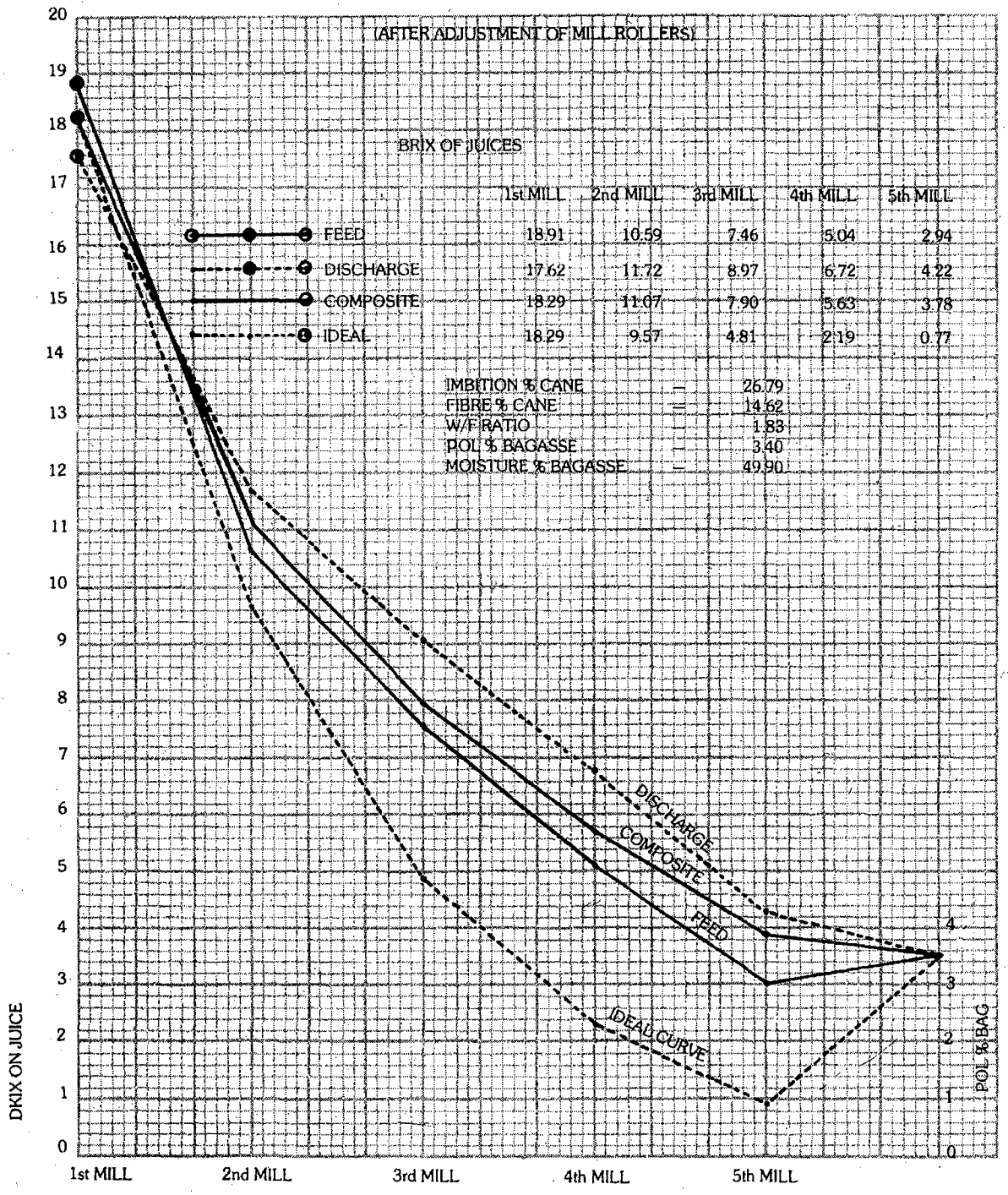
BRIX CURVE OF A 15 ROLLER PLANT



(COURTESY : CENTRAL CONTROL LAB, CAWNPORE SUGAR WORKS, MARHOWRAH)

CHART II

BRIX CURVE OF A 15 ROLLER PLANT



(COURTESY : CENTRAL CONTROL LAB, CAWNPORE SUGAR WORKS, MARHOWRAH)

If,

tray empty, M_1 = 350,22 g

tray plus bagasse, M_2 = 550,28 g

tray plus dried bagasse, M_3 = 434,24 g

then,

$$\text{Moisture \% bagasse} = \frac{(550{,}28 - 434{,}24)}{(550{,}28 - 350{,}22)} \times 100$$

$$= 58{,}00$$

Report as 58,0%

2.2.4 *Interpretation of Data :*

The weekly average results of each individual mill should be plotted on a graph with the mill numbers in ascending order on the abscissa. If all mills are performing satisfactorily the curve should show a downward slope from the first to the last mill. In the event of a mill performing inadequately its moisture content will appear above the curve.

2.2.5 *Extraction of an Individual Mill :*

Extraction of an individual mill may be calculated using brix or pol data, *e.g.* Brix extraction 3rd mill =

$$\frac{\text{Brix\% fibre 2nd mill bagasse} - \text{brix \% fibre 3rd mill bagasse}}{\text{brix \% fibre 2nd mill bagasse}}$$

Cumulative extraction upto each unit can also be calculated, *e.g.* Brix extraction after 3rd mill =

$$\frac{\text{Brix\% fibre in cane} - \text{brix \% fibre 3rd mill bagasse}}{\text{brix \% fibre in cane}}$$

Similarly pol extraction may be calculated, e.g. Pol extraction 3rd mill =

$$\frac{\text{Pol\% fibre 2nd mill bagasse} - \text{Pol\% fibre 3rd mill bagasse}}{\text{Pol \% fibre 2nd mill bagasse}}$$

2.2.6 *First Mill Extraction :*

An accurate extraction for the first unit in a milling tandem may be obtained from the analyses of first mill juice, second mill juice and mixed juice.

$$1^{st} \text{ mill extraction} = \frac{B_1 (B_3 - B_2) \times E}{B_3 (B_1 - B_2)}$$

In which, B_1 = brix % 1st mill juice

B_2 = brix % 2nd mill juice

B_3 = brix % mixed juice

E = weekly overall extraction of the tandem

9.6.6.1.1 *Example :*

If,

B_1 = 18,0

B_2 = 8,5

B_3 = 13,0

overall extraction = 96,0

$$1^{st} \text{ mill extraction} = \frac{18,0\ (13,0 - 8,5) \times 96,0}{13,0\ (18,0 - 8,5)}$$

= 63,0%

3. **Determination of Sulphur Dioxide in Sulphur-Oven Gas**

Procedure for analysis :

The method using Reich and Lunge apparatus should be followed. Arrange an apparatus as indicated in Fig. 9 where A is the pipe carrying the gas, B is a bottle containing

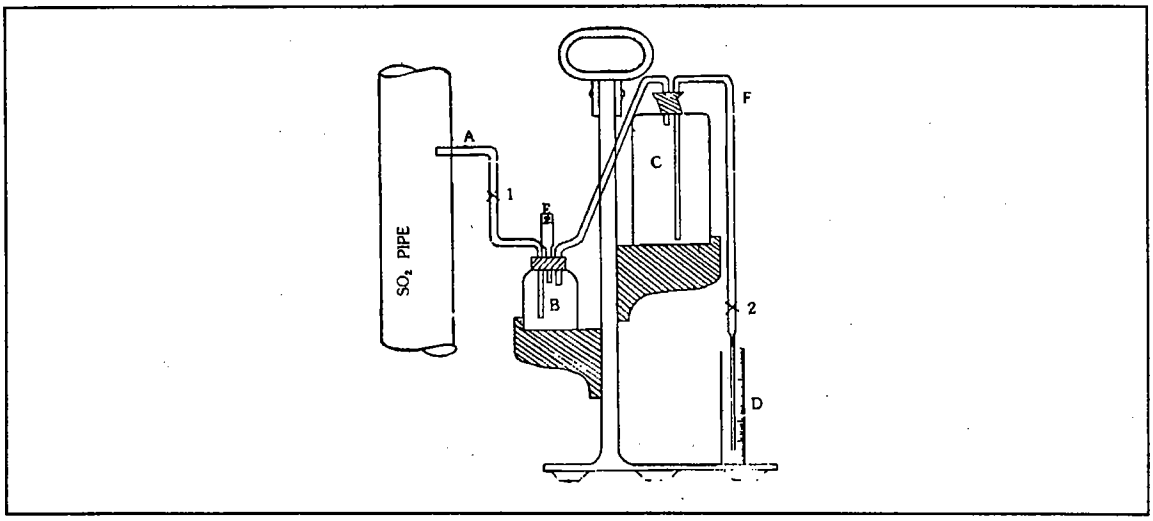


Fig. 9 : **Sketch of Reich & Longe apparatus**

10 ml of 0.1 N solution of iodine and a few drops of starch solution in a total volume of 100 ml. In making the analysis, water is allowed to discharge slowly from the aspirator bottle until the blue colour of the material in the flask is discharged. The quantity of water delivered from aspirator C is read off the graduated tube and the percentage volume of sulphur dioxide calculated from the expression

$\frac{100 \times 11.14}{V + 11.14}$ where V is the volume of water discharged from the aspirator. The derivation of expression is : 10 ml of 0.1 N iodine solution oxidises 0.032 g of sulphur dioxide which at 0°C and 60 mm occupies 11.14 ml.

The 0.1 N solution of iodine is prepared by dissolving 12.7 g iodine and 20 g of potassium iodide in a total volume of 1000 ml.

4. Determination of SO_2 in Sulphited Juice or Sulphited Syrup

Procedure :

Take 10 ml of sulphited juice or syrup in a 200 ml Erlemeyer flask. Add 10 ml of distilled water and mix by swirling motion. Take N/32 iodine solution in the burette and titrate. When pale yellow colour starts to stay for sometime a few drops of starch indicator should be added. The end point is obtained when a permanent intense blue colour is formed. The end point can be made sharp by the addition of a few drops of concentrated HCl. Then, SO_2 (mg/l) = ml of N/32 iodine solution used $\times$ 100.

5. Determination of Total Sulphur Dioxide in Sugars

5.1 In raw-sugar :

50 gms of raw sugar in dissolved in 200 ml of water, 25 ml of N sodium hydroxide solution is added and thoroughly mixed with the sugar solution. This breaks up the addition compounds of reducing sugars and sulphurous acid. A rapid stream of nitrogen is passed through the solution for at least 10 minutes to expel the air. The solution is then acidified with 10 ml of 35% sulphuric acid and immediately titrated with N/10 iodine solution and starch as indicator. A blank test is run with water instead of sugar solution and the titre of the blank is deducted from the titre of the solution. One millilitre of the N/10 iodine solution is equivalent to 3.2 mg of sulphur dioxide.

(NOTE : *The results obtained by the above method are usually higher than those of the distillation method because sugar products contain other non-sugars which are oxidised by iodine.*)

(REFERENCE : *Physical & Chemical methods of Sugar Analysis by C.A. Brown & F.W. Zerban. III Edn. 1941 pages 1068-69. For more accurate result distillation method of Monier Williams should be followed. (See pages 1066-68).*

5.2 In White-sugar :

The method is the same as above except that 100 g of sugar is dissolved in 125 to 150 ml of water and titration carried out with N/100 instead of N/10 iodine solution.

(Some sugars do not give the usual blue colour of iodine – starch but a fugitive violet. In such cases the violet colour should persist for at least 2 minutes).

Alternatively SO_2 in white sugar may be determined by the ICUMSA method described in Chapter XII.

6. **Floc Test**

The formation of a floc in the acidified sugar solutions of high density at low pH is objectionable to the bottlers and the beverage industry as a whole. Such formation of flocs or haze in the alcoholic solutions of sugar is also objectionable in the manufacture of cordials. Although attempts to develop test for accelerating such analysis have been made, but the simpler tests as described below are still used in various laboratories :

Coca Cola Test : It involves using 640 gm of sugar and 533 ml of distilled water, and 3.5 ml of 75% phosphoric acid (sufficient to give a pH around 1.5) in a jar. The jar is set aside and observed for formation of any floc on third, seventh and tenth day.

Hiram Walker Test : Dissolve 174 gm of sugar in 89.5 ml of water without the use of heat. Mix 100 ml of the water solution with 150 ml of 68.25% ethanol (by volume) and let stand for 24 hours. The mixture must have a transmission of 92% compared to water in a 50 mm cuvette at 425 nm.

Vick Test : 150 gm of sugar is dissolved in 150 ml of distilled water. Acidify the solution to ph 1.5 and mix well with 165 ml of re-distilled 95% ethanol. Keep the mixture at 37°C and examine for the presence of a floc using a light beam, at intervals of 24 hours.

Determination of free sulphur dioxide :

By free Sulphur dioxide is meant that portion which is not combined with reducing sugars but present in inorganic form. It is determined in the same manner as described above (in para 5) for the total SO_2 but the pretreatment with sodium hydroxide in omitted and only 5 ml of 35 per cent sulphuric acid is used.

7. **Carbon Dioxide in Flue and Lime Kiln Gases**

Procedure for analysis :

The most convenient apparatus for the purpose is the Orsat apparatus (Fig 10). It consists of a graduated burette A of 100 ml capacity enclosed in a cylinder filled with water. It

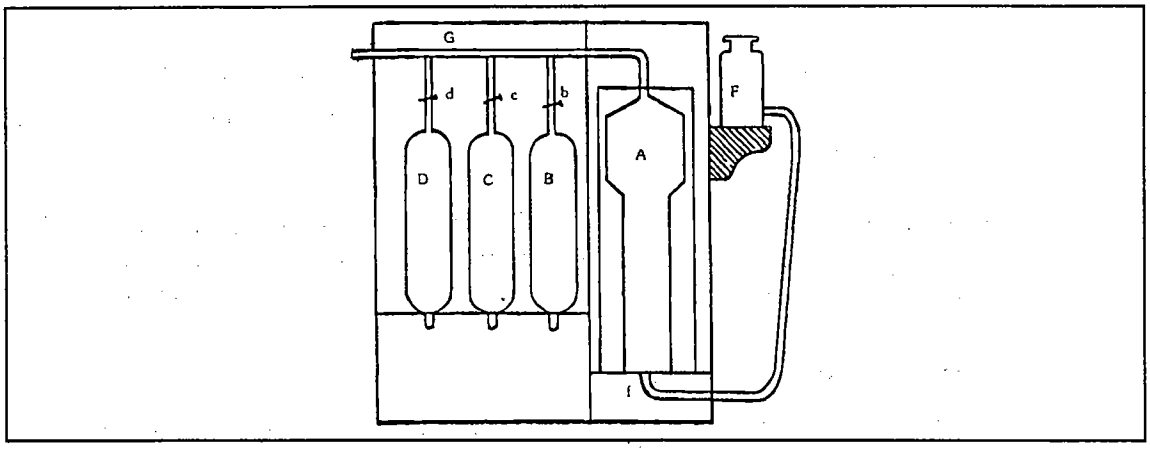


Fig. 10 : **Sketch of Orsat apparatus**

is connected to the lower end by means of a long rubber tube with a glass reservoir F. The absorption of the constituents of the gas is carried out in the bulbs B, C, D containing the appropriate absorbent materials and also partly filed with thin glass tubes to increase the surface of the absorbent. Connection to the source of supply of gas is made by the horizontal tube from the upper end of the burette A. At the end is a three way cock G. The absorbing bulbs are provided with cocks b, c and d on the tube connecting with the horizontal tube.

The absorbents used are :

For carbon dioxide : 250 g of caustic potash or 200 g of caustic soda in 1000 ml and filled in tube B.

For Oxygen : 50 g pyrogallic acid in 1000 ml of potassium or sodium hydroxide (sp. gravity 1.16) and filled in tube C.

For carbon monoxide : The tube D is to be filled with a solution of cuprous chloride prepared as follows :

Place 35 g of cupric chloride in a bottle, add 200 ml of concentrated hydrochloric acid and a quantity of copper turnings or copper foil. Stopper the bottle and set it aside for two days, shaking it occasionally, then add 120 ml water.

Ready prepared cuprous choride may be obtained from dealers and used, instead of making it in the laboratory. Twenty six gms of cuprous chloride should be dissolved in 200 ml concentrated hydrochoric acid as above, 120 ml of water added, and copper turnings or foils placed in the storage bottle. Each of the tubes in D should have a piece of copper wire in it.

(NOTE : *For H_2S or H_2SO_3 in kiln gas which can come from coke, see analysis of coke given in Chapter V*).

For the analysis of flue gases collect the sample of gas by means of an aspirator, the surface of the water in the bottle containing the gas being covered with a layer of kerosene. Connect the sample bottle to the end of the horizontal tube and fill the burette with water by raising the bottle F. Open communication to the gas and lower F and suck 100 ml of gas into the burette. Elevate F and open the connection to the bulb B containing caustic potash and force the gas into that bulb where the carbon dioxide is absorbed. Lower F and draw the residue back into the burette. Equalize the height of water in the bottle and burette and read of the quantity absorbed. By a similar procedure, the quantities of oxygen and carbon monoxide absorbed are obtained, the unabsorbed residue being recorded as nitrogen. The procedure is the same for kiln gas except that collection of the sample in an aspirator bottle is unnecessary. In kiln gas it is only necessary to determine the CO_2 content and generally this is the only determination required in flue gas.

8. **Analysis of Raw Water**

In a sugar factory, chemical examination of raw water is usually undertaken in order to ascertain its suitability as boiler feed water. The analysis should be in the order given below :

8.1 **Suspended solids :**

Dry a weighed filter paper to constant weight at 105°C. Filter through this paper 5 kilos of water keeping nearly 500 cc of the first part of the filtrate for the determination of 'dissolved solids' and the latter portion or the determination of 'ammonia and dissolved organic matter'. Dry the suspended matter in the filter paper to constant weight at 105°C. The increase in weight of the filter paper will be the total weight of the suspended solids in the volume of water used from which the suspended solids per cent can be calculated.

8.2 **Organic matter :**

Ignite the filter paper and the residue in a platinum crucible and as soon as all the carbon has been burnt away, re-carbonate with a few drops of ammonium carbonate solution, ignite again at a low temperature; cool in desiccator and weigh. The weight minus the weight of the filter paper will be the weight of the inorganic suspended matter. The weight of the suspended solids present minus that of the inorganic solids given the weight of the organic matter present.

8.3 **Dissolved solids :**

Heat a porcelain dish to redness, cool and weigh carefully. Place it on a water bath and evaporate gradually one kilogram of water. Clean and dry the outside of the dish thoroughly and heat to constant weight in an air oven. Cover the dish with a mica late whose constant weight has been previously ascertained. From the weight thus found calculate the percentage of the dissolved solids present. Reserve the residue for the estimation of nitrates.

The organic matter in dissolved solids may be determined as described in the case of suspended solids.

8.4 **Chloride :**

Reagents required :

(i) Silver nitrate solution – 2.3944 gms of the pure substance dissolved in a litre.

(ii) Potassium chromate solution – Dissolve one part of the neutral potassium chromate in 10 parts of water.

Procedure :

Measure 50 ml of the water in a porcelain dish and add three drops of solution (ii). Add solution (i) from a burette very cautiously until a faint red permanent colour is just imparted to the liquid and note the number of ml used. Repeat the same experiment with 50 ml of water and find out the number of ml of the solution used. The number in the first case minus the number of ml in the latter represents the weight of chlorine present in 100,000 parts of water.

8.5 **Nitrite :**

The amount of nitrite present in water is very small and for this a very delicate test known as the Naphthylamine sulphanilic acid test is used.

To 10 ml of the water under examination, add 1 ml of Naphthylamine sol. and 1 ml of sulphanilic acid solution. A pink colour is developed if nitrite is present.

8.6 **Sulphate :**

Acidify 500 ml of water with hydrochloric acid and evaporate to about 50 ml. Add barium chloride solution in excess. Filter, ignite and weigh the precipitate of barium sulphate. From the weight of barium sulphate, calculate the amount of the sulphate present.

8.7 **Temporary Hardness :**

Reagents required :

(i) Decinormal sulphuric acid

(ii) Decinormal sodium cabronate solution

(iii) Methyl red solution to be used as an indictor

Procedure :

Add to 500 ml of water a few drops of methyl red, then add the decinormal sulphuric acid from a burette, until the colour of the solution just changes to the red tinge. Now boil the solution to expel CO_2 and finish the titration by the addition of the necessary drops of the acid. From the number of ml of the acid used the corresponding amount of $CaCO_3$ is calculated.

8.8 **Permanent Hardness :**

To 250 ml of the water add 50 ml of decinormal sodium cabronate solution and boil for about half an hour. If magenesium salts are present, evaporate to dryness and extract the residue with water. Filter, and wash the precipitate or the insoluble matter with boiled distilled water and make the cold filtrate upto 250 ml. Now titrate 50 ml of the filtrate with the decinormal acid, using methyl red as an indicator as described above.

From the number of ml of acid which has been used, the weight of Na_2CO_3 used in precipitating the hardening salts may be found and from this the permanent hardness is calculated in terms of $CaCO_3$.

8.9 **Total Hardness :**

This may be determined by simply adding the temporary and permanent hardness.

Example :

If in actual experiment, 250 ml of water required for neutralisation, 4.2 ml of N/10 acid, from calculation we know that 1 ml of N/10 acid is equal to 0.005 gm of $CaCO_3$, therefore the amount of $CaCO_3$ present in the sample is 4.2 x 0.005 = 0.021 gm. Hence the temporary hardness as parts of calcium carbonate per 1,00,000 parts of water = 400 x 0.021 = 8.4.

In estimating the permanent hardness, 250 ml of the water are boiled with 50 ml of decinormal sodium carbonate solution. After filtration, the filtrate was made

upto 250 ml and this liquid required 8.6 ml of decinormal sulphuric acid for neutralisation; therefore the permanent hardness in the 50 ml used, corresponds to 10–8.6 = 1.4 ml of decinormal sodium carbonate solution, since 10 ml of Na_2CO_3 solution corresponding to permanent hardness in the 250 ml of the water used is 0.4 x 5.7, and since 1 ml of the sodium carbonate solution corresponds to 0.005 gm of $CaCO_3$, the permanent hardness in 1,00,000 parts = 7 x 0.005 x 400 = 14 and Total Hardness = Permanent Hardness + Temporary Hardness = 14 + 8.4 = 22.4.

9. Analysis of Evaporator Scale

A representative sample of the scale is powdered to a fine state and dried in an over for about half an hour. Five gms of this oven dry scale is weighed accurately transferred into a beaker. Concentrated HCl is added slowly till there is no effervesence of CO_2. Some more quantity of conc. HCl is added and the mixture heated to boiling. If necessary some more conc. HCl may be added. It is boiled for about one hour till most of the scale dissolves, leaving an insoluble residue. The mixture is diluted with hot water and filtered. The residue, insoluble silica, is washed till free from acid and the extract known as "acid extract" is made up to 500 ml and used for further analysis.

9.1 Insoluble Silica :

The insoluble residue on the filter paper is dried and ignited in a previously weighed crucible. It is then heated on a burner for 1 – 1½ hrs. and finally weighed till constant weight. The per centage of insoluble silica is calculated from the actual weight.

9.2 Soluble Silica :

For soluble silica 200 ml of the above extract (i.e. gms. of the scale) is taken in a porcelain dish and evaporated to dryness on a water bath. The dish is heated in an oven at 110°C. for 1 hour in order to convert the soluble silica into anhydrous insoluble condition. The dish heated in the oven is allowed to cool and gently warmed with conc. HCl which dissolves every thing except insoluble silica. Then the same mixture is again evaporated to dryness and the above operation repeated. Then conc. HCl is added and warmed gently and diluted with hot water. The solution is filtered and residue washed till free from acid. The residue is dried, ignited and weighed as soluble silica and % soluble silica is calculated.

9.3 Ferric Oxide and Alumina :

After soluble silica the total volume of the washings is made to 250 ml and 125 ml is taken for precipitation of Fe and Al. conc. HNO_3 is added to the solution to oxidise iron from ferrous to ferric condition and heated to boiling. Then a solution of strong NH_3 is added till the precipitation is complete. The ppt. is washed with hot water till free from chloride. The ppt. is dried, ignited and finally weighed as Fe_2O_3 and Al_2O_3 and per centage calculated.

9.4 Calcium :

Washings of the ppt. of Fe & Al are concentrated to a small volume by heating. Calcium is ppted as calcium oxalate by adding a hot saturated solution of ammonium oxalate in fine stream. The ppt. is digested on a sand bath for ½ hour. To the clear

solution a few drops of ammonium oxalate are added to see that the precipitation is completed. The ppt. is washed with hot water till free from chloride and oxalate. After the washing is complete the ppt. is dissolved in hot diluted H_2SO_4 and the volume is made up to 250 ml. Then 25 ml of the solution are taken and titrated against N/10 $KMnO_4$ as usual.

1 ml of $KMnO_4$ = 0.0028 gm. of CaO

= 0.0020 gm. of Ca.

9.5 **Magnesium :**

The washings of calcium are concentrated further and made slightly acidic. Then a strong sol. of NH_3 is added till neutral to methyl-orange and further quantity of 5 to 10 ml of NH_3 is added to make it alkaline. Then a 10% sol. of (microcosmic salt) sodium ammonium phosphate is added in excess and the solution is stirred vigorously without touching the sides. The whole solution is kept overnight for the precipitation to be completed. The ppt. is washed with dilute NH_4OH (1:3) solution till it gives on ppt with $AgNO_3$ after acidifying with conc. HNO_3. The ppt is dried, ignited and weighted as $Mg_2 P_2 O_7$. Wt of MgO = Wt. of $Mg_2P_2O_7$ x 0.3621 gms.

From the wt. of MgO, per centage MgO is calculated.

Acid radicals

9.6 **Original SO_4 :**

One gm. of the dry scale is accurately weighed and transferred into a beaker. Dilute HC1 (1:3) is added slowly till the effervescence cease and the evolution of CO_2 stops. Excess of dil. HCl is added and the solution is heated up to boiling. The solution is then filtered and washed till free from acid. The filtered solution is heated to boiling and to the boiling solution, 10 per cent solution of $BaCl_2$ is added slowly till the ppt. is completed. The ppt. is digested on a sand bath for ½ hour. To the clear solution a few drops of $BaCl_2$ are added to see that complete precipitation has taken place. The ppt. is dried ignited and weighed as $BaSO_4$. From the weight of $BaSO_4$ and per centage are calculated.

Wt. of SO_4 = Wt. of $BaSO_4$ x 0.4115 gms.

9.7 **Total Sulphate :**

(a) *Barium Sulphate method:*

One gm. of the dry scale is taken in a beaker and bromine water is added in excess. Dilute HCl is then added and the mixture is stirred slowly. Some more bromine water is added and the mixture is allowed to stand overnight. Next day, the mixture is boiled till all the excess bromine is expelled leaving a clear colourless solution. The solution is filtered and washed with water till free from acid. The filtrate is heated to boiling and SO_4 is ppted as $BaSO_4$ by $BaCl_2$. The ppt. is washed. Then as usual, dried, ignited and weighed as $BaSO_4$. Then total wt. of SO_4 = wt. of $BaSO_4$ x 0.4115 gms.

Per cent SO_4 due to oxidation of SO_3 to SO_4 = Total SO_4 % – original SO_4 % (i.e.) = Item No. 8.7 – Item No. 8.6

SO_3 % = SO_4 % x 0.8334

(b) *Iodine method :*

For the direct determination of SO_3, 0.5 gm. of the oven-dry scale is transferred (in duplicate) into two titration flasks having tight corks, containing 30 to 40 ml of N/10 Iodine solution which was acidified with dil. HCl. The scale should be transferred quickly in order to avoid the loss of SO_2 and the flasks are tightly corked immediately. The flasks are constantly shaken for ½ hour for the reaction to be completed. After the reaction is completed the excess of Iodine is titrated against N/10 $Na_2S_2O_3$ using starch as an indicator. The mls of N/10 Iodine consumed are determined from the titration. 1 of N/10 Iodine = 0.004003 gms. of SO_3. From the wt. of SO_3, the weight of SO_4 is calculated :

$$SO_4\ \% = \frac{SO_3\%}{0.8334}$$

9.8 **Oxalate :**

One gram of the dry scale is transferred into a beaker, dil. HC1 (1:3) is added till the evolution of CO_2 ceases. The mixture is heated for ½ hour and filtered. It is washed till free from acid. The solution is heated and neutralised by NH_4OH. It is acidified with acetic acid and a saturated solution of $CaSO_4$ is added in excess to ppt. oxalate as calcium oxalate racemate, and fluride. The ppt. is washed with water two times. Then dil. warm H_2SO_4 is added into the beaker as well as on the filter paper and solution collected in the beaker after washing. The solution is acidified with dilute H_2SO_4 and heated up to 70°C and titrated against N/10 $KMnO_4$ solution till permanent pink colour persists.

1 ml of N/10 $KMnO_4$ = 0.004401 gm. of oxalate and from this per centage is calculated.

9.9 **Phosphate :**

For the determination of P_2O_5, 50 ml of the original acid extract is taken and evaporated to 5 ml on a water bath. Then 15 ml of concentrated HNO_3 is added and then 33 ml of distilled water is added. The solution is heated to boiling. After boiling for 4 to 5 minutes, the beaker is removed from the bath and 50 ml of Lorenz reagent (a mixture of equal vol. of 16 per cent ammonium molybdate and conc. HNO_3) is added slowly with continuous stirring. The ppt. is allowed to settle for some time and filtered. The ppt. is washed with 2 per cent KNO_3 solution free from acid. The ppt. is finally washed with water. The filter paper along with the ppt. is transferred into a beaker and 50 ml of N/10 NaOH is added to dissolve the ppt. After the ppt. is completely dissolved, excess of N/10 NaOH is titrated against N/10 H_2SO_4 using phenolpthalein as an indicator and the no. of mls of N/10 NaOH required to dissolve the ppt. is calculated.

1 ml of N/10 NaOH = 0.00031 gms. of P_2O_5

9.10 **Aconitic acid :**

For the determination of aconitic acid 5 gms dry scale is transferred into a dry round bottom flask. 5 to 10 gms of potassium acetate are added and 75 ml of pure glacial acetic acid are added. The flask is connected with the air inlet tube from which CO_2 free air is passed and a condenser, and the aspirator bottle containing $K_2Cr_2O_7$ solution acidified with H_2SO_4 is connected. A slow stream of CO_2 free air is passed through the apparatus and heating the acetic acid mixture is started slowly. The reaction mixture is refluxed in 4N barium hydroxide solution using phenolpthalein as indicator. After one hour, absorption train is disconnected and barium hydroxide solution is titrated directly against N/10 HCl. The ppt. of $BaCO_3$ settles down.

1 ml of 1 N NaOH or 1 N $Ba(OH)_2$ = 0.087 gms of aconitic acid, if 1 N NaOH is used for absorption of CO_2. Methyl orange is used as an indicator.

10. **Analysis of Sugar Factory / Distillery Effluent**

The major parameters for assessing pollution potential are :

(i) Total Solids (TS)

(ii) Total Suspended Solids (TSS)

(iii) Total Dissolved Solids (TDS)

(iv) Bio-chemical Oxygen Demand (BOD)

(v) Chemical Oxygen Demand (COD)

(vi) Oxygen Absorbed Value (O.A. Value)

(vii) Ammonia

(viii) Nitrate

(ix) Nitrite

Methods of analysis in respect of above are given below :

10.1 **Total solids :**

Procedure :

Evaporate 100 ml of sample in an ignited and tared dish, dry to constant weight at 103°C, cool in a desiccator and weight. Drying for 1 hr at 103°C is usually sufficient. The samples with a pH below 4.3, NaOH is added and a pH of 4.3 maintained during evaporation. The amount of NaOH added is subtracted from the weight of residue.

Calculation :

$$\text{mg/l residue on evaporation} = \frac{\text{mg residue x 1000}}{\text{ml sample}}$$

10.2 **Suspended solids (Non-filterable residue) :**

Apparatus :

(i) Gooch crucibles, (25 ml) or Sintered glass crucible 25 ml Pore Size G-4 (See Note 2 below).

(ii) Suction apparatus

Reagent :

Asbestos cream – Make a cream by adding 10 g. acid washed, medium fibre asbestos prepared particularly for Gooch crucible determinations, to 1 litre distilled water. Some asbestos sold for this purpose contains too much asbestos powder. This fine material should be removed by repeated decantations.

Procedure :

Preparation of crucible : The asbestos mat in the Gooch crucible should be prepared with care. The mat should weigh about 0.3 g and should be approximately 2 mm thick. To prepare the mat, the crucible is first filled with asbestos cream. Let it stand 1-2 mins to allow the heavier particles to settle; then apply suction. It is important that the suction used to prepare the mat be at least as much as that which will be used in filtering the sample. After the water has been drawn through the mat, the suction is left on and the crucible is filled with distilled water, which is likewise drawn through. The procedure of washing the mat with distilled water is repeated twice more. The crucible with mat is dried in an oven at 103°C for 1 hr (30 min in a mechanical-convection oven). If the volatile matter is not to be determined, the crucible is cooled to room temperature in a desiccator and weighed.

If the volatile matter is to be determined by ignition, transfer the crucible from the oven to the muffle furnace and ignite at 600°C for 15-20 min. Remove the crucible from the furnace and, after partial cooling in the air, place it in a desiccator for 30-40 min. and weigh.

NOTE : (1) The amount of suspended matter removed during filtration depends on the thickness of the asbestos mat used in the Gooch crucible. Accordingly, a mat thickness of 2 mm is arbitrarily established in this procedure. The importance of uniform mat thickness should be recognized.

(2) If volatile matter is not to be determined, sintered glass crucibe of pore size G-4 may be used. Gooch crucibles are less commonly is use now-a-day due to difficulty in making mat and more time consuming procedure.

Treatment of Sample :

The volume of sample to be taken for filtration will depend on the concentration of suspended matter in the sample and should be as large as in practical. As a guide, 100-ml portions may be taken for sewages and industrial wastes having less than 200 mg/l suspended matter.

Measure out the well mixed sample with a wide tip pipette or a volumetric flask which has been cut down so that it will deliver the desired volume. Filter the sample through a weighed Gooch crucible, using suction. Leaving the suction on,

wash with 10 ml distilled water to remove soluble salts. Dry the crucible and solids at 103°C for 1 hr (30 min in a mechanical-convection oven) and allow it to cool to room temperature in a desiccator before weighing or dry the crucible and solids by keeping them in oven at 70° to 80°C and leaving overnight. Cool in desiccator and weigh to constant weight.

Calculation :

$$\text{mg/l of total suspended matter} = \frac{\text{mg suspended solids} \times 1000}{\text{ml sample}}$$

10.3 **Dissolved Solids (Filterable residue) :**

Dissolved matter may be obtained by difference between the residue on evaporation (9.1) and total suspended matter (9.2) or by evaporating a filtered sample as directed for residue on evaporation (9.1).

10.4 **Oxygen Demand Biochemical (B.O.D.) :**

Apparatus :

(i) Incubation bottles, 250 - 300 ml capacity, with ground-glass stoppers. Bottles should be cleaned with a good detergent and thoroughly rinsed and drained before use. As a precaution against drawing air into the dilution bottle during incubation, a water seal is recommended. Satisfactory water seals are obtained by inverting the bottles in a water bath or adding water to the flared mouth of special BOD bottles.

(ii) Air incubator or water bath, thermostatically controlled at 20°C ± 1°C. All light should be excluded to prevent formation of dissolved oxygen (D.O.) by algae in the sample.

Reagents :

(i) Distilled water : Water used for solutions and for preparation of the dilution water must be of the highest quality, distilled from a black tin or all-glass still, containing less than 0.01 mg/l copper, and be free of chlorine, chloramines, caustic alkalinity, organic material or acids.

(ii) Phosphate buffer solution : Dissolve 8.6 g KH_2PO_4, 21.75 g K_2HPO_4, 33.4 g Na_2HPO_4, $7H_2O$ and 1.7 g NH_4 Cl in about 500 ml distilled water and dilute to 1 litre. The pH of this buffer should be 7.2 without further adjustment. If dilution water is to be stored in the incubator, the phosphate buffer should be added just prior to using the dilution water.

(iii) Magnesium sulfate solution : Dissolve 22.5 g $MgSO_4$. $7H_2O$ in distilled water and dilute to 1 litre.

(iv) Calcium chloride solution : Dissolve 27.5 g anhydrous $CaCl_2$ in distilled water and dilute to 1 litre.

(v) Ferric chloride solution : Dissolve 0.25 g $FeCl_3$. $6H_2O$ in distilled water and dilute to 1 litre.

(vi) Acid and alkali soulutions 1N : For neutralization of waste samples which are either caustic or acidic.

(vii) Sodium sulfite solution, 0.25 N : Dissolve 1.576 g anhydrous Na_2SO_3 in 1,000 ml distilled water. This solution is not stable and should be prepared daily.

(viii) Seeding material : The selection of proper seed is an important factor in the BOD determination. In many cases, particularly in food-processing wastes, a satisfactory seed may be obtained by using the supernatant liquor from domestic sewage which has been stored at 20°C for 24–36 hr. Many industrial wastes contain organic compounds which are not amenable to oxidation by domestic-sewage seed. In these cases, the analyst may use seed prepared from soil; acclimated seed developed in the laboratory; or the receiving water collected below the point of discharge of the particular waste (preferably 2–5 miles below).

Procedure :

i) Preparation of dilution water : The distilled water used should have been stored in cotton-plugged bottles for a sufficient length of time to become saturated with DO. The water may also be aerated by shaking a partially filled bottle or with a supply of clean compressed air. The distilled water used should be as near 20°C as possible and of the highest purity. Place the desired volume of distilled water in a suitable bottle and add 1 ml each of phosphate buffer, magnesium sulfate, calcium chloride and ferric chloride, solutions for each litre of water.

ii) Seeding : If necessary, the dilution water is seeded by using the seed found to be the most satisfactory for the particular waste under study. Only past experience can determine the actual amount of seed to be added per litre. Seeded dilution water should be used the same day it is made.

iii) *Pretreatment :*

a) Samples containing caustic alkalinity or acidity :

Neutralize to about pH 7.0 with 1N H_2SO_4 or NaOH, using a pH meter or bromothymol blue as an outside indicator. The pH of the seeded dilution water should not be changed by the preparation of the lowest dilution of sample.

b) *Samples containing residual chlorine compounds :*

If the samples are allowed to stand for 1 to 2 hr. the residual chlorine will often be dissipated. BOD dilutions can then be prepared with properly seeded standard dilution water. Higher chlorine residuals in neutralized samples should be destroyed by adding sodium sulfite. The appropriate quantity of Na_2SO_3 is determined on a 100–1000 ml portion of the sample by adding 10 ml of 1 + 1 acetic acid or 1 + 50 H_2SO_4, followed by 10 ml KI solution (10 g in 100 ml) and titrating with 0.025 N Na_2SO_3 to the starch-iodide end point. Add to a volume of sample, the quantity of

Na_2SO_3 determined by the above test; mix; and, after 10 to 20 min. test aliquot samples for residual chlorine to check the treatment. Prepare BOD dilutions with seeded standard dilution water.

c) *Samples containing other toxic substances :*

Samples such as those from industrial wastes frequently required special study and treatment for example, toxic metals derived from electroplating wastes.

d) *Samples supersaturated with DO :*

Sample containing over 9.17 mg/lDO, at 20°C may be encountered during winter months or in localities where algae are activity growing. To prevent loss of oxygen during incubation of these samples, the DO should be reduced to saturation by bringing the sample to about 20°C in partly filled bottle and agitating it by vigorous shaking or by aerating with compressed air.

iv) *Dilution technique :*

Make several dilutions of the prepared sample so as to obtain the required oxygen depletion. The following dilutions are suggested 0.1 – 1.0 per cent for strong trade wastes; 1-5 per cent for raw and settled sewage; 5–25 per cent for oxidized effluents; 25–100 per cent for polluted river waters.

a) Carefully siphon standard dilution water, seeded if necessary, into a graduated cylinder of 1000–2000 ml capacity, filling the cylinder half full without entrainment of air. Add the quantity of carefully mixed sample to make the desired dilution and dilute to the appropriate level with dilution water. Mix well with a plunger-type mixing rod, avoiding entrainment of air. Siphon the mixed dilution into two BOD bottles, one for incubation and the other for determination of the initial DO in the mixture; stopper tightly and incubate for 5 days at 20°C. The BOD bottles should be water sealed by inversion in a tray of water in the incubator or by using a special water-seal bottle. Prepare succeeding dilutions of lower concentration in the same manner, or by adding dilution water to the unused portion of the preceding dilution.

b) The dilution technique may be greatly simplified when suitable amounts of sample are measured directly into bottles of known capacity with a large-tip volumetric pipette and the bottle is filled with just sufficient dilution water so that the stopper can be inserted without leaving air bubbles. Dilutions greater than 1:100 should be made by diluting the waste in a volumetric flask before it is added to the incubation bottles for final dilution.

10.4.1 Dissolved Oxygen (DO) :

If the sample represents 1.0 per cent or more of the lowest BOD dilution, determine DO in the undiluted sample. This determination is usually omitted in sewage and settled effluents known to have a DO content of practically zero. With samples

having an immediate oxygen demand, a calculated initial DO should be used, since such a demand represents a load on the receiving water.

Incubation :

Incubate the blank dilution water and the diluted samples for 5 days at 20°C. Then determine the DO in the incubated samples and the blank, using the Alsterberg azide method given below. Those dilutions showing a residual DO of at least 1 mg/L and a depletion of at least 2 mg/L should be considered the most reliable.

Dissolved Oxygen (DO) by Alsterberg azide Method :

Reagents :

(i) Concentrated sulphuric acid.

(ii) Maganese sulphate solution : Dissolve 364g. of $MnSO_4$, H_2O in distilled water and dilute to one litre.

(iii) Alkali Iodide in azide solution : Dissolve 500 g of NaOH (or 700 g KOH) and 135 g NaI (or 150 g. Kl) in distilled water in a one litre measuring flask. To this solution add 10 g. sodium azide (NaH_3) dissolved in 40 ml in distilled water and dilute the contents to one litre with distilled water.

(iv) Starch solution : 0.5 per cent

(v) Sodium thiosulphate solution : 0.025N

Dissolve 3.95 g. anhydrous $Na_2S_2O_3$ in one litre flask containing distilled water and make up the volume to one litre. 1 ml of 0.25N $Na_2S_2O_3$ = 0.2 mg O_2

Procedure :

To the samples in the bottles add 2 ml of manganese sulphate solution following by 2 ml of alkali iodide azide reagent, well below the surface of the liquid. Stopper the bottles with care to exclude air bubbles and mix the contents by inverting the bottles several times, when the precipitate settles leaving a clear supernatant liquid above the manganese hydroxide floc, insert 2 ml of conc. sulphuric acid and restopper it immediately. Mix the contents by gentle inversion until the precipitate is completely dissolved. The liberated iodine is then titrated against standard thiosulphate solution using starch as indicator. For titration, known amount of liquid from the bottle is taken and usual corrections are applied for the total volume of bottle content. From the titration figures of sodium thiosulphate readings the dissolved oxygen content is determined and BOD is calculated.

$$\text{BOD mg/l} = \frac{D_1 - D_2}{P}$$

D_1 = DO of diluted sample 15 min after preparation.

D_2 = DO of diluted sample after 5 days of incubation at 20°C.

P = Decimal fraction of sample used.

Seed correction :

If the dilution water is seeded, determine the oxygen depletion of the seed by setting up a separate series of seed dilutions and selecting those resulting in 40 – 70 per cent oxygen depletions in 5 days. One of these depletions is then used to calculate the correction due to the small amount of seed in the dilution water. Do not use the seeded blank for seed correction because the 5-days seeded dilution water blank is subject to erratic oxidation due to the very high dilution of seed, which is not characteristic of the seeded sample.

(vi) Dilution water control :

Fill two BOD bottles with unseeded dilution water. Stopper and water-seal one of these for incubation. The other bottle is for determining the DO before incubation. The DO results on these two bottles are used as rough-check on the quality of the unseeded dilution water. The depletion obtained should not be used as a blank correction. It should not be more than 0.1 ml.

(vii) Glucose-glutamic acid check :

The BOD test is a bio-assay procedure and consequently, the results obtained are influenced greatly by the presence of toxic substances or the use of a poor seeding material.

The standard glucose solution should show a BOD of 224 ± 10 mg/1; the standard glutamic acid solutions should show a BOD of 217 ± 10 mg/1. Any appreciable divergence from these results means that the quality of the distilled water or the seeding material is not proper. Further, if a variation greater than ± 20–22 mg/1 occurs more frequently than 5 per cent of the time, the technique used needs improvement.

To check the dilution water, the seed material, and the technique of the analyst, prepare a standard solution containing 150 mg/1 each of Analar reagent grade glucose and glutamic acid which have been dried at 103°C for 1 hr. Pipette 5.0 ml of this solution into calibrated incubation bottles, fill with seeded dilution water, and incubate with seed control at 20°C for 5 days. On the basis of a mixed primary standard containing 150 mg/1 each of glucose and glutamic acid, the 5 days BOD value varies in magnitude according to the type of seed, as shown below :

Sl. No.	**Type of seed**	**5 days seed correction mg/l**	**5 days Mean BOD mg/l**	**Standard deviation mg/l**
1.	Settled fresh sewage	0.6	218	± 11
2.	Settled stale sewage	0.6	207	± 8
3.	River water	0.05-0.22	224-242	± 7-13
4.	Activated sludge effluent	0.07-0.08	221	± 13
5.	Trickling filter effluent	0.2-0.4	225	± 8

10.4.2 Immediate Dissolved Oxygen Demand (IDOD) :

Substances oxidizable by molecular oxygen, such as ferrous iron, sulfite, sulfide, and aldehyde, impose a load on the receiving water and must be taken into consideration. The total oxygen demand of such a substrate may be determined by using a calculated initial DO or by using the sum of the immediate dissolved oxygen demand (IDOD) and the 5 days BOD. Where a differentiation of the two components is desired, it should be understood that the IDOD does not necessarily represent the immediate oxidation by molecular DO, but may represent an oxidation by the iodine liberated in the acidification step of the Winkler methods.

The depletion of DO in a standard water dilution of the sample in 15 min has been arbitrarily selected as the IDOD. To determine the IDOD, the DO of the sample (which is most cases is zero) and the DO of the dilution water are determined separately. An appropriate dilution of the sample and dilution water is prepared, and the DO is determined after 15 min. The calculated DO of the sample dilution minus the observed DO after 15 min. is the IDOD (mg/1) of the sample dilution.

Calculation :

D_0 = Dissolved oxygen of original dilution water

D_1 = Dissolved oxygen of diluted sample 15 min, after preparation

D_2 = Dissolved oxygen of diluted sample after incubation

S = Dissolved oxygen of original undiluted sample

Dc = D.O. available in dilution at zero time = D_oP+SP

n = Decimal fraction of dilution water used

P = Decimal fraction of sample used

B_1 = Dissolved oxygen of dilution of seed control before incubation

B_2 = Dissolved oxygen of dilution of seed control after incubation

f = Ratio of seed in sample to seed in control

$$= \frac{\% \text{ seed in } D_1}{\% \text{ seed in } B_1}$$

Seed correction = $(B_1 - B_2)^f$

Then,

Biochemical oxygen demand : (5 days)

a) When seeding is not required :

$$\text{mg/l BOD} = \frac{D_1 - D_2}{P}$$

b) When using seeded dilution water :

$$\text{mg/l BOD} = \frac{(D_1 - D_2) - (B_1 - B_2)^f}{n}$$

c) Including IDOD if small or not determined :

$$\text{mg/l B.O.D.} = \frac{D_0 - D_2}{n}$$

The DO determined on the unseeded dilution water after incubation is not used in the BOD calculations because this practice would over correct for the dilution water. In all of the above calculations, corrections are not made for small losses of DO in the dilution water during incubation. If the dilution water is unsatisfactory, proper corrections are difficult and the results are questionable.

10.5 **Chemical Oxygen Demand (COD) :**

Sampling and storage :

Unstable samples should be tested without delay and samples containing settleable solids should be homogenized by means of a blender for representative sampling. Initial dilutions should be made on wastes containing a high COD value in volumetric flasks in order to reduce the error which is inherent in measuring small sample volumes.

Apparatus :

Reflux apparatus, consisting of a 300 ml round-bottom flask with ground glass neck 24/40 and a Friedrichs condenser.

Reagents :

(i) Standard potassium dichromate solution, 0.25 N. Dissolve 12.259 g $K_2 Cr_2O_7$, primary standard grade previously dried at 103°C for 2 hr. in distilled water and dilute to 1000 ml.

(ii) Sulfuric acid, Conc. (Analar)

(iii) Standard ferrous ammonium sulfate solution 0.25 N. Dissolve 98 g Fe $(NH_4)_2 (SO_4)_2.6H_2O$, cool, and dilute to 1000 ml. This solution must be standardized against the $K_2Cr_2O_7$, daily.

Standardisation :

Dilute 25.0 ml. standard dichromate solution to about 250 ml. Add 20 ml conc. H_2SO_4 and allow to cool. Titrate against the ferrous ammonium sulfate using 2 or 3 drops of ferroin indicator.

$$\text{Normality} = \frac{\text{ml } K_2Cr_2O_7 \text{ x } 0.25}{\text{ml Fe } (NH_4)_2 (SO_4)_2}$$

(iv) Ferroin indicator solution :

Dissolve 1.485 g, 1, 10-phenanthroline monohydrate, together with 0.695 g $FeSO_4.7H_2O$ in water and dilute to 100 ml. This indicator solution may be purchased already prepared.

(v) Silver sulfate, crystals

Procedure :

i) Place a 50.0 ml. sample, or an aliquot diluted to 50 ml. with distilled water, in a round bottom flask and add 25 ml standard dichromate solution. Carefully add 75 ml. H_2SO_4 mixing after each addition.

(CAUTION : The reflux mixture must be thoroughly mixed before heat is applied. If this is not done, local heating occurs in the bottom of the flask and the mixture may be blown out side the arm of the condenser).

ii) Attach the flask to the Friedrichs condenser and reflux the mixture for 2 hrs. (A shorter period may be used for particular wastes if it has been found to give the maximum COD). Pumice granules or glass beads should be added to the reflux mixture to prevent bumping, which can be server and dangerous; cool and then wash down the condenser with about 25 ml. distilled water.

iii) Transfer the contents to a 500-ml conical flask, washing out the reflux flask 4-5 times with distilled water, dilute the mixture of about 350 ml and titrate the excess dichromate, after cooling to room temperature, with standard ferrous ammonium sulfate, using ferroin indicator. Generally 2-3 drops of the indicator and used. This, however, depends upon the individual analyst. The colour change is sharp, going from a blue green to a reddish blue. The end point, however, will not be as sharp as in the standardization of the reagents because of the higher acid concentration in the sample. For this reason, it is necessary that the samples be diluted to at least 350 ml before the titration is carried out.

iv) A blank consisting of 50 ml. distilled water instead of the sample, together with the reagents, is refluxed in the same manner.

v) More namely complete oxidation of many organic compounds such as straight-chain alcohols and acids, may be obtained by the use of silver sulfate as a

catalyst : 1g Ag_2SO_4 is added directly to the mixture before refluxing, or the silver sulfate may be dissolved in H_2SO_4 at the rate of 1g for every 75 ml acid.

vi) For dilute samples, the dichromate solution is diluted to 0.025 N. Extreme care must be taken with all glassware at this concentration because the slightest trace of organic matter in the condenser or atmosphere will cause gross errors. Only the samples with approximately 50 per cent reduction of the chromate will be reasonable accurate. A dilute ferrous ammonium sulfate solution, 0.025N, should be used for the back titration. This concentration must be made with excess acid or diluted afresh daily.

vii) For handling the chloride interference with carbonaceous wastes, the mixture of sample, dichromate and acid is heated to boiling for 20 min. without any silver sulfate catalyst. The heat is removed and the digesting mixture cooled enough to handle and prevent excessive vapour loss. Then 1g of catalyst is added and the digestion is continued.

Calculation :

$$\text{mg/l COD} = \frac{(a - b)\ c \times 8000 - d}{\text{ml sample}}$$

Where :

COD = Chemical Oxygen Demand from dichromate

a = ml Fe $(NH_4)_2\ (SO_4)_2$ used for blank

b = ml Fe $(NH_4)_2\ (SO_4)_2$ used for sample

c = Normality Fe $(NH_4)_2\ (SO_4)_2$

d = Cl correction = mg/l Cl x 0.23

10.6 **O.A. Value :**

Estimation of the oxygen consumed by the organic matter, by the Forschammer of Oxygen process.

The estimation enables a judgement to be formed as to the total amount of oxidisable matter present in water. This may include not only organic matter, but such reducing substances as nitrites, ferrous salts or sulphuretted hydrogen.

The process consists in mixing a known volume of the water, acidified with dilute sulphuric acid with a known volume in excess of standard potassium permanganate solution. The mixture is allowed to stand for a definite time at a difinite temperature and the excess of the permanganate remaining after the oxidation is estimated.

It is customery to treat two samples of the water with the permanganate and to submit them to a temperature of 27°C. The first is maintained at this temperature

for three minutes, and the second for four hours. This procedure gives some indication of the nature of the reducing substance, since nitrites, ferrous salts or sulphuretted hydrogen will reduce the permanganate immediately, whereas the organic matter reacts quantitively with the permanganate only after a considerable time.

Reagents :

(i) Solution of potassium permanganate. Dissolve 0.395 gm. of pure potassium permanganate in 1000 ml. of water. Each millilitre of this solution contains 0.1 milligram of oxygen available for oxidation.

(ii) Sodium thiosulphate solution. Dissolve 2.5 gm. of pure recrystallised sodium thiosulphate in 1 litre of water.

(iii) Dilute sulphuric acid. Dilute one volume of pure sulphuric acid with three volumes of water, and add $KMnO_4$ solution to the liquid until a very faint, but permanent, pink colouration has been obtained.

(iv) Potassium iodide solution. Dissolve 1 part of pure potassium iodide in 10 parts of water.

(v) Starch solution. Dissolve 1 part starch in 100 parts of boiling water and use the clear, cold solution.

The process of estimating the oxygen required by the organic matter :

Rinse out two 500 ml. stoppered flasks (marked A and B), first with pure sulphuric acid to destroy organic matter, and then with distilled water. Measure 250 ml. of the water under examination into each flask. Place the flasks in a water both or air bath which is kept at a temperature of 27°C by means of a suitable regulator. When the contents of the flask have attained the temperature of the bath, measure into each of them 10 ml. of the standard potassium, permanganate solution (i) and 10 ml. of the dilute sulphuric acid (ii) and mix the liquid by shaking. Then restopper the flasks and place them again in the bath, preferably keeping them in the dark during the reaction.

If the pink colour at any time disappears from water in the flask, start the process afresh with 20 ml. of the permanganate solution; or if the pink colour is seen to be diminishing rapidly, add a further 10 ml. of permanganate solution.

At the end of three minutes take (A) out of the bath and add 5.0 ml potassium iodide solution (iv). The pink colour of the liquid will change to yellow, since the oxygen of the permanganate liberates its equivalent of iodide. Add the sodium thiosulphate solution (ii) from a burette, untill the colour of the liquid in the flask fades to a pale straw tint. At this stage add 1 ml. of fresh starch solution (v). A deep blue colour will appear. Gradually add more thiosulphate until the solution becomes colourless.

After the flask (B) has been kept for four hours at 27°C, take it out of the bath and titrate its contents in the same way.

A blank experiment on 250 ml. of pure distilled water should be carried out side by side with the samples, the flask containing this water being allowed to stand for four hours 27°C. The titration figure obtained is in effect a standardisation of the thiosulphate against the permanganate, under the conditions of the experiment.

Calculation :

Let 'A' represent the number of millilitres of thiosulphate solution which have been used in the titration of the permanganate in the distilled water, and 'B' the number of millillitres used in the titration of the permanganate in the water under examination. Then A – B is the number of millilitres of thiosulphate solution which are equivalent to the permaganate reduced by the water.

Further, if the amount of available oxygen in the 10 ml. of permanganate originally added is represented by A, then the weight of oxygen required to oxidise the organic matter in 250 ml. of the water will be

$$\frac{A - B}{A}$$

But a = 0.001 gm of oxygen and 250 ml. of water were used, therefore the amount of oxygen consumed by 1000000 parts of the water :

$$\frac{(A-B)\times 0.001\times 106}{A\times 250}\times\frac{A-B}{A}\times 0.9$$

10.7 **Ammonia – Titrimetric Method – Detectable Limit: >5 mg/L NH_3 - N**

Measurement :

10.7.1 *Principle*

The sample containing ammonia is buffered at pH 9.5 with a borate buffer and distilled in a Kjeldahl distillation unit. The distillate is collected in the boric-acid-solution-containing indicator. The level of NH_3 is estimated by titration with 0.02 N H_2SO_4 titrant. The occurrence of a pale lavender colour indicates the end point.

NOTE : The sample is buffered to control the hydrolysis of cyanates and other nitrogen-containing organic compounds.

10.7.2 *Apparatus*

a) Kjeldahl distillation unit – This unit consists of a Kjeldahl flask of 800-ml capacity connected to a condenser through an adapter. The tip of the condenser is attached to a delivery tube that reaches to the bottom of the receiver, which collects the distillate. The unit is shown in Fig. No. 11.

b) Oven – set at 103°C

c) Desiccating cabinet

d) Volumetric flasks – of different capacities

e) Measuring cylinders – of different capacities

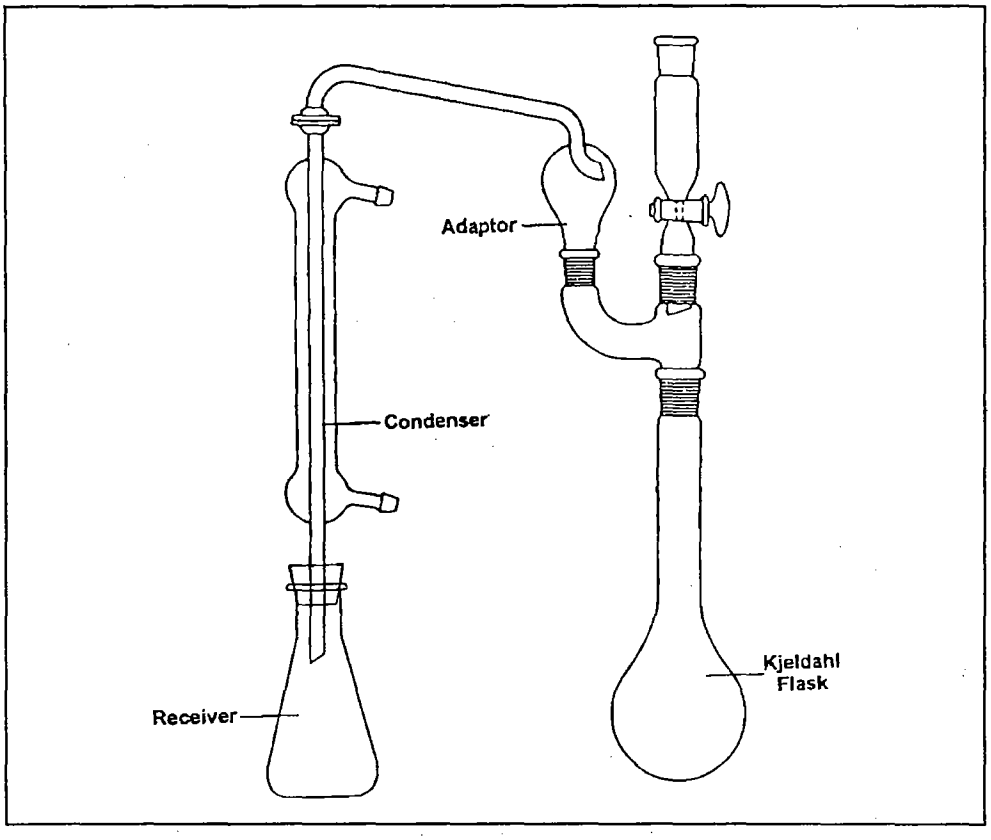


Fig. 11 : **Kjeldahl distillation unit**

10.7.3 *Reagents*

Prepare all reagents in NH_3-free water.

a. Ammonia-free water (AFW) : Single distilled water is usually not free from ammonia. Hence, DDW should always be used.

b. Sodium hydroxide, NaOH; 0.1 N.

c. Borate buffer solution : Weigh 4.95 gm sodium tetraborate ($Na_2B_4O_7$) or 9.45 g $Na_2B_4O_7.10H_2O$ and transfer to a 1-L volumeteric flask. Dissolve in fresh AFW. Add 88-ml of 0.1 N NaOH solution. Dilute upto the mark with AFW.

d. Sodium hydroxide, NaOH; 6.0 N.

e. Dechlorinating agent, Sodium thiosulfate $Na_2S_2O_3.5H_2O$; 0.014 N: Weigh 0.35 g $Na_2S_2O_3.5H_2O$ and transfer to a 100 ml volumetric flask. Dissolve in fresh AFW and dilute to 100 ml.

f. Neutralizing solutions :

i) Sulfuric acid, H_2SO_4; 1 N.

ii) Sodium hydroxide, 1N.

g. Indicating-boric-acid solution :

i) Mised indictor : Solution A – Weight 0.3 g methyl red indicator and transfer to a 250-ml volumetric flask. Dissolve in 150 ml 95% ethyl alcohol.

Solution B – In another 100 ml volumetric flask weigh 0.15 g methylene blue and dissolve in 100 ml 95% ethyl alcohol.

Add solution B to solution A. Mix thoroughly to make 250 ml solution of uniform consistency.

ii) Indicating-boric-acid solution : Weight 20g baric acid, H_3BO_3, and transfer to a 1-L volumetric flask. Dissolve in fresh AFW. Add 10 ml mixed indicator solution in it. Bring the final volume to 1 L with AFW.

NOTE : Prepare fresh solution every month.

h. Standard H_2SO_4 titrant, 0.02 N : Prepare and standardize 0.02 N H_2SO_4 standard solution.

1 ml 0.02 N $H_2SO_4 \equiv 280$ µg N

i. Stock ammonium chloride, NH_4Cl solution :

i) Keep an adequate quantity of ammonium chloride in an oven at 103°C for 1 h. Cool to room temperature in a desiccating cabinet.

ii) Weigh accurately 3.819 g NH_4Cl and transfer to a 1-L volumetric flask. Dissolve in fresh AFW. Dilute with AFW up to the mark.

1 ml stock NH_4Cl solution $\equiv$ 1.0 mg NH_3 – N

NOTE : This solution is stable for about six months.

j. Standard ammonium chloride, NH_4Cl solution : Measure 5 ml of stock NH_4Cl solution in a 500 ml volumetric flask and dilute up to the mark with fresh AFW.

1 L NH_3 – N in standard solution $\equiv$ 10 mg/L

10.7.4 *Standardization*

Prepare a standard in duplicate with 500 ml standard NH_4Cl solution and follow the same procedure as described below for the sample.

10.7.5 *Procedure*

a) Preparation of distillation apparatus :

i. Into four Kjeldahl distillation flasks measure 500 ml fresh AFW. Add 20 ml borate buffer to each flask.

ii. Adjust pH of solution in each flask to 9.5 with 6 N NaOH solution.

iii. Add a few clean, dry glass beads to the flasks to control bumping.

iv. Place all the flasks on heater and assemble the Kjeldahl unit as shown.

v. Bring the solution to a boil.

vi. The steam thus produced will clean and make the distillation apparatus free of ammonia before use.

vii. Continue this process until the distillate is completely free of ammonia.

viii. Repeat this procedure each time if the apparatus is not in use for a period of 4 hr or more, which is enough to accumulate ammonia in the apparatus.

b) Preparation of sample :

i. If the sample contains residual chlorine, add a quantity of dechlorinating reagent in proportion to the residual chlorine present in the sample in accordance with following relation :

1 ml of dechlorinating reagent ≡ 1 mg/L residual chlorine

ii. The volume of sample for distillation should be selected according to Table given below :

Volume of sample taken for Distillation in the Analysis of NH_3 – N

Range of NH_3 – N in sample (mg/L)	Volume of samples, ml
5 – 10	250
10 – 20	100
20 – 50	50
0 – 100	25

c) Distillation of sample

i. Measure 500 ml dechlorinated sample or an aliquot diluted to 500 ml with AFW in distillation flask.

ii. Adjust pH of sample to neutral with neutralizing solution, *i.e.*, either 1 N NaOH or H_2SO_4 as required.

iii. Add 25 m borate solution and adjust pH to 9.5 with 6 N NaOH.

iv. Measure 50 ml indicating-boric-acid reagent in receiver. Immediately start distillation.

NOTE : Distillation of sample must start immediately after steam cleaning of distillation assembly to avoid contamination.

v. The rate of distillation shall be adjusted in the range of 6 – 10 ml/min.

vi. Collect the distillate in the receiver.

NOTE : The tip of delivery tube shall be submerged in the indicating boric acid solution placed in the receiver.

vii. Collect about 30 ml distillate. Lower the receiver (no contact with tip of delivery tube). Continue distillation for 1 or 2 min more to clear the condenser and delivery tube. Replace the receiver with a conical flask.

viii. Continue distillation to concentrate the residue left in Kjeldahl flask (approximately to 50 ml volume). Collect the distillate in a conical flask.

ix. Do not preserve the excess distillate.

x. Preserve the residue left in the distillation flask for organic nitrogen determination, if required.

xi. Use distillate collected in the receiver for the estimation of NH_3 – N.

d) Estimation of NH_3 – N

i. Dilute 300 ml distillate to 500 ml with AFW.

ii. Titrate it with standard 0.02 N H_2SO_4 titrant until a pale lavender color is developed. This is the end point.

10.7.6 *Calculation*

$$\text{mg } NH_3 - N = \frac{(A - B) \times N \times E \times 1000}{\text{volume of sample, ml}}$$

Where A = volume of H_2SO_4 titrant used for sample, ml

B = volume of H_2SO_4 titrant used for blank, ml

N = normality of H_2SO_4 titrant

E = quivalent mass of N

Since, N = 0.02 and E = 14, the above relation can be modified as follows :

$$\text{mg } NH_3 - N = \frac{(A - B) \times 0.02 \times 14 \times 1000}{\text{volume of sample, ml}} = \frac{(A - B) \times 280}{\text{volume of sample, ml}}$$

10.8 **Nitrate – Colorimetric Method – Detectable Range : 0.1 to 2.0 mg/L NO_3 – N**

Measurement :

10.8.1 *Principal*

The nitrate content present in the sample produces yellow color on reaction with brucine solution under acidic conditions. The absorbance of color is measured at 410 nm. The intensity of color is directly proportional to the amount of NO_3 present in the sample.

NOTE : a. This estimation reaction is an exothermic reaction, *i.e.*, heat is generated during the reaction. The estimation of NO_3 is significantly affected by heat generated during the reaction, so the reaction temperature must be controlled during the estimation.

b. This procedure can be used for water samples with high salinity also.

10.8.2 *Apparatus*

a. UV Spectrophotometer – Any commercially available model set at 410-nm wave-length.

b. Mechanical pipettes – with varying capacities.

c. Hot water bath – to maintain a temperature of sample flask between 90 and 95°C.

d. Cool water bath – maintain water temperature at 10–20°C.

e. Volumetric flasks – 100 ml capacity

f. Filtration unit

g. Test tubes – Pyrex glass

10.8.3 *Reagents*

a. Nitrate-free water (NFW): Use DDW to prepare all the reagents and solutions.

b. Dechlorinating reagent, sodium arsenite solution, $NaAsO_2$: Weigh 0.5 g $NaAsO_2$ and transfer to a 100 ml volumetric flask. Dissolve in NFW. Dilute up to the mark.

c. Brucine – sulfanilic acid solution: Weigh 1 g brucine sulfate and 0.1 g sulfanilic acid and transfer both chemicals to a 100 ml volumetric flask. Dissolve in approximately 70 ml hot NFW. Now add 3.0 ml concentrated HCl to the flask. Cool the solution to room temperature and bring up the final volume to 100 ml.

NOTE :

(1) Brucine sulfate and sodium arsenite are toxic in nature, hence avoid ingestion or any contact with skin.

(2) Sulfanilic acid is used to remove the interference caused by nitrites (NO_2) present in the sample upto 0.5 mg NO_2 – N/L Level.

d. Sulfuric acid solution 4:1 H_2SO_4: Measure 100 ml NFW in a 1-L beaker. Carefully add 400 ml concentrated H_2SO_4 to NFW. Cool the solution to room temperature.

NOTE : This reaction is highly exothermic, so this dilution must be done in a fume hood.

e. Sodium chloride, NaCl: Weigh 300 g NaCl and transfer to a 1 L volumetric flask. Dissolve in NFW and dilute to 1 L volume.

f. Stock nitrate solution, anhydrous KNO_3 :

i) Dry an adequate quantity of anhydrous KNO_3 in an oven set at 103°C for 1 h. Cool to room temperature in a desiccating cabinet.

ii) Weigh accurately 7.218 g dry and cool KNO_3 and transfer to a 1 L volumetric flask. Dissolve in NFW. Finally, bring its volume to 1 L with NFW.

1 ml of stock solution ≡ 1 mg NO_3 – N

NOTE : This solution is stable for six months.

g. Standard Nitrate solution : Measure 10 ml of stock nitrate solution in a 1 L volumetric flask. Dilute up to the mark with NFW.

1 ml of standard solution ≡ 0.01 or 10 µg NO_3 – N

10.8.4 *Standardization*

Prepare calibration standards containing 0.5, 1.0, 1.5 and 2.0 mg/L NO_3 – N and standardize as follows :

a. Into four 100-ml volumetric flasks, measure 5, 10, 15 and 20 ml standard nitrate solution.

b. Dilute solution in each flask with NFW up to the mark.

c. Divide 10-ml volume of each standard solution into four different test tubes.

d. Use the same procedure for development of color as described below for the sample.

e. Prepare a blank with NFW instead of sample and set the spectrophotometer to zero at 410 nm.

f. Draw a calibration curve of absorbance against concentration of NO_3 in mg/L.

10.8.5 *Sample Preparation*

a. If sample contains suspended matter, filter it through GF/C filter paper.

b. If sample contains residual chlorine, add 0.05 to 0.10 ml (1 or 2 drops) of sodium arsenite solution to neutralize.

10.8.6 *Procedure*

a. Begin with clean, dry test tubes.

b. Measure 10-ml sample or an aliquot diluted to 10-ml in a test tube. Always prepare each sample in duplicate.

c. Prepare a blank using 10 ml NFW instead of sample.

d. Add 2 ml NaCl solution to each tube containing sample. Mix thoroughly by swirling.

e. Add 10-ml of 4:1 H_2SO_4 solution. Mix again thoroughly.

f. Cool test tubes in a water bath containing water at 10–20°C.

NOTE : If at this point any turbidity appears, take the sample in spectrophotometric cell and read its absorbance at 410 nm. Record this value, as it represents the sample blank.

g. Add 0.5-ml brucine-sulfanilic acid reagent. Swirl the tubes thoroughly for uniform mixing. Avoid the formation of air bubbles.

h. Place test tubes in hot water bath maintained at 90–95°C for 20 min.

i. After 20 min remove the tubes and place in the cool water bath maintained at 10–20°C.

j. When the thermal equilibrium is attained, remove the tubes from the water bath.

k. Set zero with DDW blank or sample bank.

l. Read the absorbance of yellow color developed in a spectrophotometer set at 410 nm against blank or sample blank.

m. Read the concentration of NO_3 – N directly from the standard curve.

10.8.7 *Calculation*

$$\text{mg } NO_3 - N/L = \frac{\mu g\ NO_3 - N}{\text{volume of sample, ml}}$$

mg NO_3/L = mg/L nitrate N x 4.43

where

$$4.43 = \frac{\text{equivalent weight of } NO_3}{\text{equivalent weight of N}} = \frac{62}{14}$$

10.9 **Nitrite – Diazotization Method – Detectable Range : 1.0 to 300 µg / L NO_2 –N**

Measurement :

10.9.1 *Principle*

Nitrite present in water or wastewater undergoes diazotization on reacting with sulfanilamide under acidic conditions. The product is then coupled with N-(1-naphthyl) ethylenediamine dihydrochloride to produce a reddish-purple azo dye. The absorbance of azo dye is measured on a spectrophotometer set at 550 nm.

10.9.2 *Precautions*

a. Nitrite in the sample should be measured immediately after sample collection to avoid its microbial conversion to NO_3 or NH_3. Even if the sampling bottle is sterilized, the natural bacterial life in water may cause this conversion.

b. If samples are to be stored. The estimation should be done within no more than 24 h of sample collection.

10.9.3 *Apparatus*

a. U.V. spectrophotometer – Any commercially available model set at 550 nm.

b. Mechanical pipettes – with varying capacity.

c. Volumetric flasks – 100 ml capacity.

d. Beaker – 50 ml capacity.

e. Filtration unit.

10.9.4 *Reagents*

a. Nitrite-free water (NFW): Use DDW for this purpose.

b. Hydrochloric acid, HCl, 20% (v/v) solution : Measure 50 ml of NFW in a 100-ml volumetric flask. Carefully add 20 ml concentrated HCl. Dilute upto the mark with NFW.

c. Sulfanilamide solution : Weigh 0.5 g sulfanilamide and transfer to a 100-ml volumetric flask. Dissolve in minimum amount of 20% (v/v) HCl. Markup the final volume to 100 ml.

d. Hydrochloric acid, HCl; 1% (v/v) solution : Add 1.0 ml concentrated HCl in 100-ml volumetric flask containing 50 ml NFW. Dilute up to the mark with NFW.

e. N-(1-Naphthyl) ethylenediamine dihydrochloride solution : Weigh 0.3 g of the solid reagent and transfer to a 100-ml volumetric flask. Dissolve in 1% (v/v) HCl solution. Makeup the final volume to 100 ml with 1% (v/v) HCl.

f. Aluminum chloride, $AlCl_3$

g. Stock nitrite solution :

i) Place an adequate quantity of potassium nitrite, KNO_2, in a 50-ml beaker and keep for 24 h for drying in a desiccator containing concentrated H_2SO_4 (sp. Gr. 1.84).

ii) Weigh accurately 0.6072 g dried KNO_2 and dissolve in minimal volume of NFW with stirring.

iii) Transfer the solution to a 1L volumetric flask and make the volume up to the mark with NFW.

iv) Preserve the solution with 2 ml chloroform.

v) Store the solution in a sterilized Pyrex bottle under refrigeration.

1.0 ml stock nitrite solution ≡ 100 µg NO_2 – N

NOTE :

(1) Potassium nitrite is readily oxidized in the moisture, so fresh bottles of reagent must be used for the preparation of stock solution.

(2) If properly stored, the stock solution is stable for about 1 month.

(3) To achieve more accuracy, determine the nitrite content in stock solution before use by adding an excess of standard potassium permanganate, $KMnO_4$. The color of $KMnO_4$ is discharged with a standard reductant, ferrous ammonium sulfate and finally, back-titrating with standard permanganate solution.

h. Standard nitrite solution : Measure 1.0 ml of stock nitrite solution in a 100-ml volumetric flask. Dilute to 100 ml with NFW.

1.0 ml standard nitrite solution ≡ 1.0 µg NO_2 – N

NOTE : This solution is unstable. Always prepare fresh standard solution for each estimation.

10.9.5 *Standardization*

Prepare calibration standards containing 1, 1, 30, 50, 100, 200 and 300 µg NO_2 – N/L concentration and calibrate by following procedure :

a. Into seven different 100-ml capacity volumetric flasks, measure 0.1, 1, 3, 5, 10, 20 and 30 ml standard nitrite solution.

b. Dilute solution in each flask upto the mark with NFW and mix thoroughly.

c. Prepare a blank in duplicate with NFW instead of standard solution.

d. Develop color in standards and blank as described below for the sample.

e. Record the absorbance at 550 nm and plot a calibration curve of absorbance against the concentration of NO_2 – N µg/L.

10.9.6 *Procedure*

a. Removal of turbidity and color :

i) If the sample contains suspended solids, add a few drops of aluminum hydroxide, $Al(OH)_3$ suspension per 100-ml sample.

ii) Stir thoroughly and allow to stand until the flocs settle down.

iii) Filter through GF/C filter paper.

iv) If coloration remains, prepare a sample blank. To 10-ml sample add 1-ml sulfanilamide and record the absorbance at 550 nm.

b. Development of color :

i) Measure 100-ml sample or an aliquot diluted to 100 ml into a 250-ml Erlenmeyer flask. The temperature of sample must be maintained at room temperature (25°C).

ii) Add 2 ml of sulfanilamide solution and mix well. Wait 5 min for reaction.

iii) Add 2 ml of naphthyl ethylene diamine solution. At this stage, pH should be less than 2.0. Wait for 10 min.

iv) Measure the absorbance after 10 min in a spectrohotometer set at 550 nm against a DDW blank or sample blank.

v) Calculate the concentration of NO_2 – N from the calibration curve.

10.9.7 *Calculation*

$\mu g\ NO_2 - N/L = (A - B) \times df$

Where A = absorbance reading for sample

B = absorbance reading for blank or sample blank

df = dilution factor

If 10 ml of sample is diluted to 100 ml, df = 10.

If 20 ml of sample is diluted to 100 ml, df = 5.

If 1.0 ml of sample is diluted to 100 ml, df = 100.

$mg/L\ NO_2 = mg/L\ NO_2 - N \times 3.29$

Where

$$3.29 = \frac{\text{equivalent weight of } NO_2}{\text{equivalent weight of N}} = \frac{46}{14}$$

11. **Tolerance Limits (General) in respect of essential characteristics of Treated Effluents discharges are given in table No. 6 below :**

Table No. 6

Sl. No.	Characteristics	Into Inland Surface Water	On land for irrigation
1.	Disolved solids (Inorg.) mg/1; (Max)	2100	2100
2.	pH value	5.5 to 9.0	5.5 to 9.0
3.	Temperature °C/Max. (within 15 meters of outlet)	Not to exceed 40	–
4.	Oil and Grease, mg/1, (Max.)	10	10
5.	Ammonical Nitrogen (as N) mg/1, (Max)	50	–
6.	Total nitrogen as (N) (Kjeldahl), mg/1, (max)	100	–
7.	Free Ammonia, mg/1, (Max)	5	–
8.	B.O.D. (5 days) at 20°C (Max)	30*	100
9.	C.O.D., mg/1, (Max)	250	–
10.	Colour and odour	Absent	–
11.	Suspended solids mg/1, (Max)	100	200
12.	Particle size of suspended solids	To pass through 850 micron IS sieve	

(See IS 2490 Part II 1974)

* For distilleries the limit of 30 for BOD value may be relaxed upto a value of 100 mg/1.

Note : Distillery effluents should as far as possible be discharged on land for irrigation rather than in surface waters.

CHAPTER – V

ANALYSIS OF MATERIALS USED IN SUGAR MANUFACTURE

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1. Analysis of Limestone:

Sampling

Collect from different trucks or heaps of the consignment, about 50 Kg of as representative a sample of limestone as possible. This should be broken into very small pieces and reduced to a coarse powder which should be quartered and requartered. About 500 g of this should be air dried and further pulverised to a fine powder which should pass through a sieve with mesh opening of 0.1mm. It should then be further subsampled to about 100g.

Analysis

The analysis of limestone comprises the determination of (a) moisture, (b) organic matter (c) solids insoluble in hydrochloric acid (d) silica (e) iron and aluminium oxide (f) magnesium oxide (g) sulphates (h) calcium oxide and (i) carbon dioxide.

1.1 Moisture

The moisture percentage is determined by heating 10 grams of the air-dry pulverized sample for two hours at 102 - 105°C. Weigh after cooling in a desiccator. Difference in weight, multiplied by ten, gives the percentage of moisture.

1.2 Organic Matter

The percentage of organic matter is determined by heating one gram of the sample in a platinum crucible over a Bunsen burner for 10 minutes, followed by heating over a blast lamp for 10 minutes. The percentage of organic matter is calculated from the loss of weight by allowing for the percentage of moisture and carbon dioxide.

1.3 Solids Insoluble in HCL

The percentage of solids insoluble in hydrochloric acid is determined by adding 50 ml of water and 25 ml of concentrated hydrochloric acid to 10 grms of the sample in a 300 ml conical flask. After effervescence has stopped. 0.5-1 ml of concentrated nitric acid is added and the mixture is boiled for 5 minutes. If only a few insolubles are present the contents of the flask are diluted to 200 ml and at boiling temperature enough of a 10 per cent ammonia solution is added to colour litmus paper slightly blue. The solution is boiled for a few minutes and the precipitate is allowed to settle and then filtered. The precipitate is quickly and completely washed with a hot 2 per cent ammonium nitrate solution; filtrate and washings being collected in 1 litre graduated flask and used for the determination of magnesium and sulphate.

The washed precipitate on the filter is now repeatedly rinsed with hydrochloric acid (1:1) and washed with hot water until chlorides can no longer be detected in the washings. Filtrate and washings are collected in a 350 ml porcelain dish and used for the determination of silica and sesquioxides. The wet filter and precipitate are ignited till constant weight is obtained.

If a considerable amount of insolubles is present, they are filtered before silica and sesquioxides are precipitated with ammonia. The precipitate is washed with boiling water, ignited and weighed. Filtrate and washings collected in a 500 ml conical flask are diluted with hot water to 200 ml and silicic acid and sesquioxides are precipitated, filtered, washed and redissolved as previously described. Filtrate and washings are used for the determination of magnesium oxide and sulphates.

1.4 **Silicic Acid:**

The percentage of silicic acid is determined by completely evaporating the solution of silicic acid and sesquioxides para 2 of section 1.3 above on a waterbath. The residue is moistened with concentrated hydrochloric acid and again evaporated to dryness. This process is repeated. Finally, the porcelain dish is heated in an oven for two hours at 120^{0}C. After cooling, the residue is moistened with hydrochloric acid and allowed to stand for 10 minutes. 50 ml of hot water are added, the mixture is heated to boiling, stirring all the time, and the now insoluble silicic acid is filtered. Filter and precipitate are washed with hot water. The wet filter containing the silica is ignited in a platinum crucible. Do not allow the filter to catch fire. Finally cover the crucible and ignite over the blast lamp.

1.5 **Iron and Aluminium Oxide:**

The percentage of iron and aluminium oxide is determined by diluting the filtrate and washings of the silica determination in a 500 ml conical flask to a volume of 200 ml. Ammonia (10 per cent solution) is added till litmus paper is coloured slightly blue. The solution is boiled for 5 minutes and the precipitate is allowed to settle. The precipitate is then filtered and the filter and precipitate are washed with a 2 per cent ammonium nitrate solution. Filtrate and washings are also collected in the 1 litre graduated flask mentioned in para 2 of 1.3 above.

The wet filter containing the sesquioxides is ignited in a platinum crucible. Since aluminium tends to retain moisture, ignition over a blast lamp or in an electric furnace is essential.

1.6 **Magnesium Oxide:**

The percentage of magnesium oxide is determined in the contents of the one litre graduated flask mentioned under (1.3) and (1.5). After cooling, the flask is filled to the mark and the contents are well mixed by shaking.

400 ml of this solution are placed in a 700 ml conical flask and heated to the boiling point after which excess of 12 per cent ammonium oxalate solution is added. The mixture is boiled for a few minutes and allowed to stand in a hot place for two hours. After cooling, liquid and precipitate are rinsed into a 500 ml graduated flask, which is then made up to the mark. After mixing, the contents are filtered, the first 10 ml being discarded. 250 ml of the filtrate are collected in a graduated flask of this size and then evaporated in a porcelain dish till the volume is approximately 50 ml. The concentrate is quantitatively rinsed into

a 250 ml beaker and diluted with water to approximately 100 ml. After heating the liquid to the boiling point, 10 ml of a 10% ammonium phosphate solution and three drops of phenolphthalein are added in that order. The liquid is then stirred with a glass stirrer while enough drops of concentrated ammonia are added to colour it a definite red shade. While the stirring is continued, an excess of 10 per cent ammonia equal to $1/5^{th}$ of the total volume is added and the beaker and contents are allowed to cool. After at least four hours the ammonium phosphate is filtered. Filter and precipitate are efficiently washed with 2.5 per cent ammonia and the filter is dried.

As much as possible of the precipitate is carefully transferred into a prepared platinum crucible and the filter is ashed above the crucible in a platinum spiral, the ash being collected in the crucible. The precipitate is first carefully ignited, then strongly ignited, over a blast lamp. If, after ignition, the pyrophosphate is not completely white, then moisten with a little nitric acid, evaporate to dryness on a waterbath and ignite till constant weight is obtained.

The percentage of MgO is found with the formula :

$$\frac{\text{weight of } Mg_2P_2O_7 \text{ x } 0.3622 \text{ x } 5}{\text{weight of limestoe analysed in grams}} \text{ x } 100$$

1.7 Sulphates:

The percentage of sulphates is determined in 200 ml of the contents of the one litre graduated flask mentioned under (1.3) and (1.5). This volume is concentrated to approximately 50 ml and quantitatively rinsed into a 250 ml beaker. Hydrochloric acid (1:1) is added till litmus paper is coloured slightly pink. One more ml of hydrochloric acid is added and the sulphates are precipitated at boiling temperature with approximately 5 ml of a 10 per cent barium chloride solution. The solution is boiled for a few minutes and allowed to stand for four hours in a hot place. The $BaSO_4$ is filtered and completely washed and filter and precipitate are then dried. As much as possible of the precipitate is carefully transferred into a prepared platinum crucible and the filter ashed above the crucible in a platinum spiral, the ash being collected in the crucible. The precipitate is ignited, cooled, and moistened with a few drops of 50 per cent sulphuric acid in order to convert small amounts of barium sulphide into barium sulphate. The crucible is first heated on an air-bath till white fumes no longer escape and then ignited till constant weight is obtained.

The percentage of sulphate (as SO_3) is found with the formula:

$$\frac{\text{weight of } BaSO_4 \text{ in grams x } 0.3429 \text{ x } 5}{\text{weight of limestone analysed in grams}} \text{ x } 100$$

1.8 Calcium Oxide

The percentage of calcium oxide is determined by weighing and transferring 0.5 grams of the sample into a 300 ml conical flask. 100 ml of water are added, the flask is covered with a small funnel and 3 ml concentrated hydrochloric acid are added. On completion of the reaction, a few drops of nitric acid are added. The

mixture is boiled for a few minutes and impurities are precipitated by adding 10 per cent ammonia solution till litmus paper is coloured slightly blue.

The precipitate is filtered and washed with a hot 2 per cent ammonium nitrate solution. Filtrate and washings are collected in a 400 ml beaker and after dilution of the contents to 200 ml., calcium is precipitated by adding 20 ml. Of a hot ammonium oxalate solution (4 per cent) at the boiling point. The liquid is boiled for a few minutes and allowed to stand for 4 hours in a hot place. The supernatant liquid is decanted through a filter and the precipitate washed by repeatedly adding hot water, which, after settling, is decanted through the filter. This process is continued till the washings no longer contain chlorides. The filter is placed above the beaker and perforated with a platinum wire. Calcium oxalate which may be present is then rinsed into the beaker. For rinsing, 10 ml of hot diluted sulphuric acid (1:5) is used twice and hot water is used several times until the total volume is approximately 250 ml.

After addition of 20 ml sulphuric acid (1:1) the oxialic acid is titrated with N/5 potassium permanganate.

The percentage of calcium oxide is calculated with the formula:

$$\frac{\text{ml of permanganate x titre of permanganate x } 0.028}{\text{weight of limestone analysed in grams}} \times 100$$

1.9 Carbon Dioxide

The percentage of carbon dioxide is usually determined by multiplying the percentage of calcium oxide by 0.7851 and adding the percentage of magnesium oxide multiplied by 1.091.

1.10 Purity of Limestone (Schroeter method):

While occasional complete analysis of limestone is advisable, as a check, routine determination of $CaCO_3$ content will, in the absence of substantial quantity of magnesium carbonate, give sufficient information about the quality of limestone. For this purpose CO_2 determination is made with the help of Schroeter apparatus shown in figure No. 12.

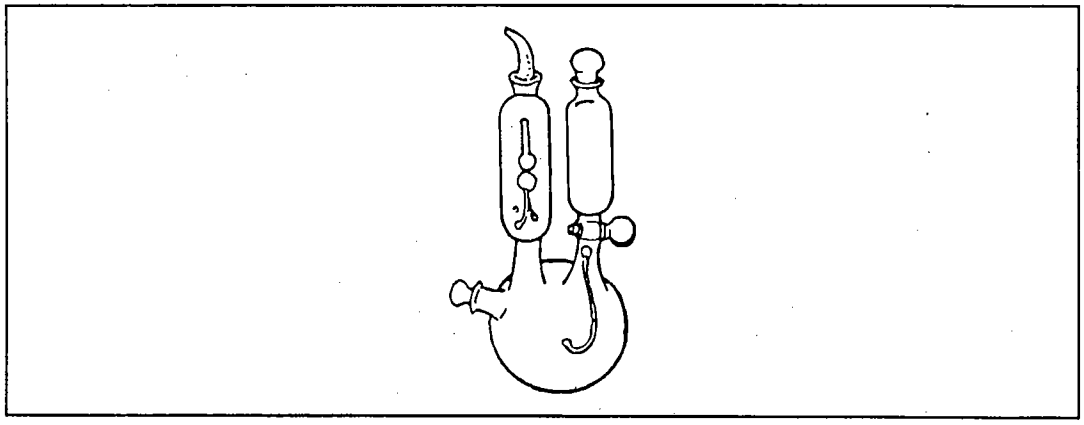

Fig. 12 : Schroeter Apparatus

Fill the tube on the right with 1:1 hydrochloric acid and that on the left with conc. Sulphuric acid. Transfer 0.2 g of material to the bottle and weigh the apparatus. Allow the acid (HCl) in the tube on the right side to enter the bottle drop by drop unil solution is complete. CO_2 escapes through the tube containing H_2SO_4 which will absorb the water vapour which may be carried away by the CO_2 gas. Heat gently on sand bath until all CO_2 is expelled. Cool and weigh the apparatus and record the difference as the weight of CO_2 Then –

$$CaCO_3\% = \frac{100}{44} \times \frac{\text{Wt. of } CO_2}{0.2} \times 100$$

2. Analysis of Lime:

Sampling:

Sampling lime is similar to sampling limestone. The repeatedly quartered and crushed sample has to be taken to the analytical laboratory in an air-tight tin.

Analysis:

For rapid assessment of the quality of lime, the percentage of available CaO should be determined and a 'slakability' test should be carried out in order to determine the percentage of 'dead burnt' lime which hydrates slowly giving slowly increasing pH values in limed and heated juices during settling.

2.1 Available CaO:

2.1.1 *Phenol Method:* About 2.5 grams of the pulverised lime samples are carefully weighed into a weighing bottle and afterwards quantitatively rinsed into a graduated flask of 250 ml. Rinsing liquid is a 5 per cent aqueous phenol solution. After at least one hour, in which the flask is frequently shaken, the volume is made up to the mark, the phenol solution again being used for this purpose. The contents are well mixed and quickly filtered through a folded filter paper. The first 50 ml are discarded.

100 ml. of the clear filtrate are pipetted into a beaker and titrated with N/1 hydrochloric acid, methyl orange being used as indicator.

The percentage of available CaO is calculated from the following formula:

$$\frac{\text{Number of ml HCl x titre HCl x 2.5 x 0.028}}{\text{Weight of lime dissolved in grams}}$$

2.1.2 *Sucrose Method:* Weigh rapidly and accurately 5 g of finely powdered lime sample on a watch glass. Transfer it to a 250 ml volumetric flask with 75 to 90 ml of freshly boiled distilled water. Boil gently on a hot plate shaking with a rotary motion to break up the lumps if any. Cool the flask to room temperature. Dissolve 40-45 g of pure sugar in 40 ml freshly boiled distilled

water and then add this to the flask with the lime. Shake vigorously for 30 minutes with rotary motion keeping the lime in suspension. Complete to volume with freshly boiled distilled water and shake well. Then filter, using Wattman No.1 filter paper. Discard first 25–50 ml of filtrate. Pipette 25 ml of the filtrate into a cleaned 250 ml Erlenmeyer flask. Add 5 drops of phenolphthalein indicator and titrate to absence of pink colour, with standard N/2.8 H_2SO_4.

Thus % available CaO = ml of N/2.8 H_2SO_4 used in titration x 2

2.2 **Slakability Test:**

About 500 g of lime in pieces which have previously been reduced to a size of 2 to 3 cm are accurately weighed then repeatedly rinsed with small quantities of pure water in a suitable vessel. A considerable amount of heat is evolved and the pieces will disintegrate within a few minutes. More water is added till appearance of the mixture is that of a thick mash. Wait exactly 10 minutes from the beginning of the addition of water and then dilute the mixture sufficiently to produce a thin milk of lime, which is strained through a sieve with openings of 0.1 mm. The residue while carefully being rubbed over the gauge is washed with water till the washings are clear. It is then collected in a previously tared porcelain basin, dried at 105^{0}C and weighed.

A second test is made in which the thick lime-water mixture is diluted after one hour's waiting instead of ten minutes. In both cases the residue has to be calculated as a percentage of the original weight of lime used for the test.

If the residue after 10 minutes is 4 – 10% weight of sample and after one hour 2-7%, the quality is satisfactory. If it is more in either case, the quality is unsatisfactory.

Complete Analysis of Lime:

Sampling

This is done as under 2 above. The pieces from the tin are crushed into a coarse powder and kept in a stoppered bottle. As lime rapidly attracts carbonic acid and moisture from the atmosphere, the sampling should be done very quickly.

2.3 **Matter insoluble in hydrochloric acid:**

5 gms. of the coarse lime powder are placed in a beaker; about 50 ml of water are added and after the lime has slaked, sufficient hydrochloric acid is gradually added till no more dissolves. A few mls of nitric acid are run into the solution, which is boiled and filtered through an ash-free paper into an Erlenmeyer flask of about 300-400 ml capacity. The insoluble part remaining on the filter paper is washed with hot water, till the filtrate shows a neutral reaction, after which it is dried and burnt in a platinum crucible. The weight of the ash is that of the insoluble matter from 5 gms. of lime.

2.4 **Silica:**

The filtrate from the foregoing operation, which together with the wash water will occupy a volume of 200-300 ml is heated to boiling point and nearly neutralized

with ammonia, leaving the liquid only faintly acid and absolutely clear. This solution is boiled gently for one or two minutes and a few drops of ammonia added, rendering it slightly alkaline. After boiling for a short time, it is then allowed to subside and is filtered into a litre flask, the filter being washed thoroughly. The precipitate consists of silica, together with alumina, iron oxide and perhaps traces of lime; it is dissolved from the filter paper in dilute hydrochloric acid and the paper washed with water.

The solution together with the wash water is evaporated in a porcelain dish to dryness and heated in an air-bath at a temperature of 120 - 140^{0}C for one hour. The dry residue is moistened with a few drops of strong hydrochloric acid, diluted with water, heated and filtered through an ash-free filter paper which is washed. The filter paper with its contents is dried, and incinerated in a platinum crucible. The weight of the ash is that of the silica in 5 gms. of lime.

2.5 **Iron oxide and Alumina:**

The filtrate and wash waters from the silica determination are heated to boiling in an Erlenmeyer flask and nearly neutralized with ammonia so that the liquid remains only faintly acid and completely clear. It is boiled gently for one or two minutes and rendered alkaline by means of a few drops of ammonia. The precipitate is collected on an ash-free filter paper, washed, dried and incinerated in a platinum crucible. The weight found on this occasion is that of the iron oxide and alumina in 5 gms. of lime.

2.6 **Calcium oxide:**

The filtrate and wash waters of the foregoing operations, which may contain some lime-salts, are added to the liquid in the litre flask, which had been filtered off from the first precipitation with ammonia. The liquid is cooled to room temperature, made up with water to the mark and well shaken (Solution A). 50 ml of this are diluted with about 200 ml of hot water in a beaker or an Erlenmeyer flask; a little ammonia is added, and the mixture brought to the boil, after which the lime is precipitated by a solution of ammonium oxalate. The liquid is kept in a warm place for a couple of hours, preferably on a hot air-bath, and at the end of that time filtered through an ash-free filter paper, after ensuring that any further addition of the ammonium oxalate reagent produces no further precipitation. The precipitate on the filter is washed with water, till the washings no longer become turbid with nitric acid and silver nitrate. The lime may be weighed either as oxalate or as carbonate.

In the first case, the precipitate is filtered through a dry tared paper, that is a paper which has previously been placed in a drying-bottle, dried at 100^{0}C in an air-bath and weighed. The washed paper containing the precipitate is replaced in the drying-bottle, which is again heated in the air-bath at 100^{0}C until its weight is constant.

The weight found for the calcium oxalate with its water of crystallization, is multiplied by the factor 0.3836 in order to find the weight of the calcium oxide in 0.250 gm. of lime.

In the second method the dried filter paper with the calcium oxalate is incinerated in a platinum crucible till the filter is completely burnt; the residue is moistened with a few drops of ammonium carbonate solution, the excess of which is expelled by heating on the water-bath, any calcium oxide being thus converted into the carbonate again. As soon as the mass in the crucible has become dry, it is carefully heated for about five minutes by a very small flame, cooled and weighed. The weight found multiplied by the factor 0.56 is that of the calcium oxide in 0.250 gm. of lime.

2.7 **Magnesia:**

400 ml of solution A are transferred into a 500 ml measuring flask, treated with ammonia until alkaline, and with ammonium oxalate solution until all the lime is precipitated. In order to make sure that this has really taken place, it is advisable to add 6 gms. of ammonium oxalate dissolved in 50 ml of hot water. The liquid is cooled to room temperature, made up to the mark, shaken and filtered; 250 ml of the filtrate are concentrated on the water-bath to a volume of about 50 ml and hydrochloric acid is added till the reaction is distinctly acid in order to dissolve again some magnesia which might have become insoluble during the evaporation. The liquid is rendered alkaline again by ammonia, is next filtered and the insoluble residue washed with a little water.

The solution and the wash water are mixed and precipitated with sodium phosphate, the liquid being stirred with a glass rod, which is softly rubbed against the inside of the beaker. After a quarter of an hour about one-fourth of the volume of ammonia is added, and the mixture is allowed to stand for 12 hours in a cold place.

The precipitate is collected on an ash-free filter paper and washed with 3% ammonia solution until the washings no longer become turbid with nitric acid and silver nitrate. Sometimes the precipitate adheres so strongly to the glass that it cannot be removed with a glass rod bearing a rubber cap. In that case as much of the precipitate as possible is collected on the filter, and the rest dissolved in a drop of hydrochloric acid; this solution is rendered alkaline with 3 per cent ammonia and the precipitate thus obtained is combined with the first after standing for 2 hours. The filter with the combined precipitate is washed several times with the dilute ammonia solution and dried in an air-bath.

The dry precipitate is transferred as completely as possible into a platinum crucible, while the filter with the precipitate which could not be removed is incinerated on the cover of the crucible and the ash added to the original quantity in the crucible, the whole being heated first over a small flame and finally over the blow-pipe. The complete whiteness of the heated matter may be promoted by moistening it during a pause in the incineration with, at most, two or three drops of nitric acid-on no account more.

The residue obtained is magnesium pyrophosphate, the weight of which is calculated to magnesia by multiplying with the factor 0.3624, which gives the amount of magnesia in 1 gm. of the lime.

2.8 **Sulphuric Acid:**

200 ml of solution A are precipitated while boiling with a hot solution of barium chloride, placed on a hot air-bath for a couple of hours filtered through an ash-free filter paper. The precipitate is washed with water until the washings no longer become turbid with silver nitrate, after which it is dried and incinerated. The residue is removed from the paper as completely as possible to the platinum crucible while the paper is burnt on the cover. Both portions are combined and strongly heated, after which the crucible is cooled and weighed. The weight found, multiplied by the factor 0.3432 is that of the amount of sulphuric acid (SO_3) in 1 gm. of the lime.

2.9 **Carbonic Acid:**

A portion of the sample is ground in a mortar to a fine powder and 3 gms. weighed into Schroeter apparatus. This apparatus is first weighed empty, after which about 3 gms. of the lime are placed in the flask, the apparatus being weighed again to ascertain exactly the weight of the material employed. 10 ml of water are added to the lime, the closed funnel is filled with strong hydrochloric acid; and the bulb through which the carbonic acid gas escapes is filled with just so much concentrated sulphuric acid as to prevent back-suction. The whole apparatus is wiped dry on the outside, put aside for half-an-hour, and then weighed.

Next the hydrochloric acid is allowed to flow from the funnel into the flask gradually by carefully opening the cock, and as soon as all the lime is dissolved, the flask is carefully heated over a very small flame till the liquid commences boiling. A narrow rubber tube is connected with the opening, through which the carbonic acid has escaped; the cock of the hydrochloric acid funnel is opened; and a slow current of air is sucked through the apparatus till the gas no longer tastes of carbonic acid. The apparatus is left to cool and is weighed again, preferably by leaving the original weights on the right-hand pan while the difference is made up by placing small weights on the same pan as the apparatus.

The decrease in weight represents the carbonic acid (CO_2) in the amount of lime examined.

2.10 **Alkalies:**

Into a large flask containing 1500 ml of water 150 gms of the coarsely powdered lime are added in small quantities, and the mixture shaken continuously till all the lime is slaked. As soon as this point is attained, the liquid is filtered through a dry paper and 100 ml of the filtrate are measured.

A current of carbonic acid is conducted through the hot solution, which is heated, the precipitate filtered off, and the solution evaporated almost to complete dryness. The last traces of calcium oxide are precipitated by a few drops of ammonia and ammonium oxalate as insoluble calcium oxalate; the liquid is filtered from the precipitate into a platinum dish and the filter washed. Filtrate and wash waters after being rendered acid with hydrochloric acid are evaporated to dryness and gently heated over a small flame to drive off the ammonium chloride. The residue is weighed as potassium and sodium chloride, and after multiplication by the factor 0.6319 yields the amount of alkali, calculated as potash (K_2O) in 100 gms. of lime.

2.11 Water:

As the water is chemically combined with the calcium oxide, it cannot be driven off at 110^0C, and a much higher temperature must be employed. 3 gms. of coarse powder are heated in a porcelain or platinum crucible., covered with a lid for a quarter of an hour over a gas or spirit lamp, cooled in a desiccator and weighed. The loss sustained on heating is the weight of water in 3 gms. of lime.

The crucible is preferably of platinum and is narrow in shape. It must remain covered with the lid while heating, for if this is not done the lime may absorb carbonic acid from the products of combustion, the water content thus being found too low, and sometimes actually an increase in weight is observed.

The results of the analysis may be stated in the following form:

Calcium Oxide	...	95.32
Magnesium Oxide	...	0.07
Carbonic Acid	...	0.91
Insoluble in hydrochloric acid	...	0.46
Silica	...	0.05
Iron oxide and alumina	...	0.18
Sulphuric acid	...	none
Alkalies	...	0.02
Water	...	2.89
Undetermined	...	0.10
		100.00

2.12 Rapid method for estimation of magnesia in lime:

The method of determination of magnesia being rather a lengthy one, a rapid method for detecting, approximately, whether the lime contains too much magnesia or not is often employed, especially as it is not always necessary to know the exact magnesia content. It is only needed to ascertain whether magnesia content of lime is above or below 2 per cent. 1 gm. of the finely powdered lime is mixed with 10 ml of water and heated; hydrochloric acid is added drop by drop until almost all the lime is dissolved and the liquid is alkaline. It is then boiled, filtered and ammonia added to the filtrate. If now a white gelatinous precipitate is formed, the lime contains over 2 per cent of magnesia and should not be used; if a flocculent cloudy precipitate is formed, the content is between 1 and 2 per cent; while an amount of less than 1 per cent escapes detection by this rough method of estimation.

3. Analysis of Coke:

Sampling

Lumps of coke are taken at random from the heap and broken to pieces of the size of an egg. The sample thus obtained is well mixed and piled in a heap; a segment is taken from it which is mixed again and piled in a smaller heap, till a subsample

of about one Kg is obtained. This is beaten to small pieces which are again mixed, while finally a portion of the last subsample is ground to a very fine powder kept in a stoppered bottle.

Analysis:

3.1 **Moisture:**

5 gms of the fine powder are dried to constant weight at 100^0-105^0C in an air-bath, which generally required 2 or 3 hours to complete. The loss of weight multiplied by 20 represents the moisture in gms in 100 gms. of coke.

3.2 **Ash:**

2 gms. of the very finely powdered coke are spread in a thin layer on a platinum dish and heated first on a small flame and afterwards at gradually increasing temperatures, until at least the heating is completed at a very high temperature. The carbon is consumed and the ash remains behind; but to make sure that really all the carbon has been burnt, the ash which has been cooled and weighed is treated with a little strong alcohol. If carbon is still present, this floats and then the alcohol is evaporated and combustion pursued till all the carbon has vanished. The weight of the ash is divided by 3 and multiplied by 100 in order to find the gms of ash on 100 gms. of coke.

This determination must be made in a muffle furnace. The dish with the 3 gms of coke is placed in the cold muffle and the temperature gradually raised.

3.3 **Sulphur in Coke:**

Sulphur occurs in the coke in two forms viz., as sulphate (gypsum) or as sulphide (chiefly as pyrites). It is principally the sulphur occurring as sulphides which has a harmful action in the kiln. since it forms sulphurous acid on combustion which attacks the pipes and the pump. This sulphur is called 'harmful sulphur' in distinction to the sulphur in the form of sulphate which is harmless.

3.3.1 *Total Sulphur:*

0.5 to 1 gm. of the finely powdered coke is thoroughly mixed in a platinum crucible with 1 gm. of magnesium oxide and 0.5 gm., of anhydrous sodium carbonate; the crucible is placed at an angle and heated during several hours till all the carbon is burnt. The mixture is stirred, now and then with a platinum wire.

After being cooled down, the contents of the crucible are transferred with a jet of water into a beaker, and bromine solution is added till the yellow colour remains, after which the mixture is boiled with an excess of hydrochloric acid. The harmful sulphur which had been oxidized to sulphite during the combustion is oxidized to sulphate by the bromine and dissolved by the hydrochloric acid. The liquid is boiled till the colour of bromine is driven off, filtered, the residue washed with water, and the sulphuric acid precipitated with barium chloride.

By multiplying the amount of barium sulphate weighed, by the factor 0.137, the total sulphur in 1 gm. of coke is found.

It is understood that both the magnesia and the sodium carbonate used must not contain any sulphate, and if that is not so, then the sulphuric acid is determined in the amount of the reagents used, and allowance made in the calculation.

3.2.2 *Harmless Sulphur:*

This is determined by heating the ash of 5 or 10 gms. of coke with hydrochloric acid and a few mls of bromine solution; this latter addition serves to re-oxidize that part of the sulphate which, on combustion, might have been reduced to calcium sulphite. The liquid is filtered, boiled till odour of bromine can no longer be detected, after which the sulphuric acid is determined in the usual way.

3.3.3 *Harmful Sulphur:*

This is found by subtracting the percentage of the harmless sulphur from that of the total sulphur in the coke.

Loss of weight on heating in a current of nitrogen:

5 gms. of coke are heated in a Rose crucible for 2 hours at 110°C–120°C to drive off the moisture. The crucible is weighed after cooling, after which it is heated for 15 to 30 minutes over a large flame, while a slow current of dry nitrogen gas is conducted through the crucible. After cooling the crucible is weighed again, the loss of weight representing the tarry substance in 5 gms. of coke.

The nitrogen gas is prepared by heating a solution of 2 parts of potassium nitrite and 1 part of ammonium chloride in a large flask. The flask is connected with a gas holder by a wide tube.

When determining the loss on heating, the gas is conducted first through a wash-bottle filled with concentrated sulphuric acid, and the current in regulated in such a way that only one gas bubble passes per second.

4. **Analysis of Sulphur:**

4.1 **Moisture:**

Heat 100 g of pulverized sample at 70°C in watch glass. Weigh, after cooling in a desiccator. Difference in weight gives per cent of moisture.

4.2 **Percentage of Sulphur:**

Take 10 gms of properly mixed sample in a small beaker. Add sufficient carbon disulphide to dissolve all the sulphur. Decant the carbon disulphide. Heat the residue for about ½ hour at 100°C. Add more carbon disulphide and dissolve more sulphur if possible. Decant the CS_2 and wash several times with the same. Allow the beaker to stand for some time when the CS_2 will evaporate. Weigh the beaker and residue.

$$\% \text{ residue} = \frac{\text{Wt. of residue x } 100}{10}$$

% of sulphur = 100 – (% moisture + % residue)

4.3 **Ash:**

Take 10 g of sample in a crucible. Heat till the sulphur inflames. Ignite the residue after the sulphur has burnt off. Cool and weigh.

$$\% \text{ Ash} = \frac{\text{Wt. of residue}}{10} \text{ x } 100$$

4.4 **Combustibility:**

An opinion about the combustibility of the sulphur can be formed by watching the combustion of the sample in the crucible used for ash determination.

Sulphur containing high percentage of ash or organic substances which tend to carbonize in the combustion process and form a film which prevents complete combustion is less suitable for closed type of burners. Not only is the combustion process retarded but a considerable amount of sulphur may be lost in slag.

Moreover the sulphur if heated till inflammation occurs, should burn completely without additional supply of heat. No film should be formed on the molten sulphur and the residue should not be more than 1 per cent of the weight of the sulphur. For sulphur to be used in rotary burners, in which the burning surface of the molten mass is contiuously refreshed, a higher figure is tolerable.

4.5 **Arsenic:**

Only qualitative test is recommended. Take 1.0 g of sample in a test tube. Add 15 drops of ammonia and 2 ml of water. Shake for half an hour. Filter the solution. Add 30 drops of 1:1 HCl to the filtrate. Further add 15 drops of 15 per cent solution of oxalic acid. Put in this solution a small piece of copper or brass which previously has been cleaned with emery paper. Heat to boiling. Take out the metal piece and watch. If arsenic is present the piece would be covered by a grayish brown or black film.

5. **Analysis of Commercial Phosphoric Acid and Acid Phosphates:**

5.1 **Phosphoric Acid:**

Procedure:

Weigh out accurately 2 g of commercial phosphoric acid in a ground stoppered weighing bottle. Transfer quantitatively into a 250 ml volumetric flask and make upto mark and shake well. Titrate 25 ml portion with standard (carbonate free) normal sodium hydroxide solution.

Add alpha – naptholphthalein-phenolphthalein mixture as indicator. The end point is violet coloured. Take two or three readings which should not differ by more than 0.5 ml.

Calculation:

1.0 ml of normal NaOH = 0.04902 g of H_3PO_4.

5.2 **Acid Phosphates** (Single, double or triple superphosphate):

5.2.1 *Free Phosphoric Acid:*

20 gms of the well mixed sample are treated in a litre measuring flask with about 800 ml of water and shaken for half an hour. The liquid is filled up to the mark and then filtered.

100 ml. equivalent to 2 gms of the sample are transferred to a beaker and after the addition of a few drops of phenolphthalein, the solution is titrated with normal sodium hydroxide solution from a burette till a faint pink colouration is produced.

As phenolphthalein shows neutrality as soon as the disodium salt is formed every ml of the normal soda solution is equivalent to 0.0355 gm of phosphorus pentoxide (P_2O_5) or to 0.049 gm of orthophosphoric acid (H_3PO_4).

Example :

Suppose 20.9 ml of normal soda solution were required the phosphate salt would contain –

$$\frac{20.9 \times 0.0355}{20} \times 1000 = 37.11\% \text{ of } P_2O_5$$

or

$$\frac{20.9 \times 0.0049}{20} \times 1000 = 51.20\% \text{ of } H_3PO_4$$

5.2.2 *Total Phosphoric Acid:*

25 ml of the above mentioned solution of 20 gms of the phosphate salt in one litre are transferred into a beaker and almost entirely neutralized with ammonia. 50 ml of citrate solution, (150 gms of citric acid are dissolved in 500 ml of water. To this 500 ml of ammonia of Sp. Gr. 0.94 are added and the mixture diluted to 1500 ml), are added and if all the turbidity does not disappear at once some more of the solution may be added till perfectly clear and strongly alkaline liquid is obtained. This is cooled by placing the beaker in cold water and then 25 ml of magnesia mixture are added slowly with constant stirring. After half an hour about 10 per cent by volume of ammonia is added and the beaker is left at rest for 12 hours to allow the precipitate of ammonium magnesium phosphate to settle down. The addition of magnesia mixture must be done immediately after cooling, otherwise calcium phosphate may crystallize out. The precipitate is collected on ash free filter-paper and treated in the same manner as the precipitate of

ammonium magnesium phosphate is treated in the determination of magnesia in lime.

The precipitate is finally weighed as magnesium pyrophosphate and by multiplying the weight found, by the factor 0.64, that of the quantity of P_2O_5 is calculated.

6. **Analysis of Blankit (Sodium Hydrosulphite, $Na_2S_2O_4$) :**

5.0 gms of Blankit are dissolved in 100 ml cold water to which 0.5 ml ammonia has been added. Since moist Blankit is rapidly oxidized by air, quick working is essential and care should be taken that moist Blankit particles do not adhere to the wall of the flask. 4.0 gms. of indigo carmine (Indigo sodium sulphonate) are dissolved in water and the volume is made upto one litre. 250 ml of the carmine solution, equivalent to 0.3325 gm hydrosulphite, are placed in a 500 ml flask and Blankit solution is added from a graduated pipette until the blue colour has changed to yellow. The result of this titration is provisional and in the final test 90 per cent of the volume found in the provisional test, is added at once and the titration is then completed in the usual way. If k ml of the Blankit solution are used in the titration, the $Na_2S_2O_4$ per cent is given by $\frac{665}{k}$.

7. **Analysis of Electrolytic Chlorine (E.C.):**

The chlorine content of E.C. is determined as follows:

Solution required:

0.1N solution of iodine in potassium iodine and 20 gms of potassium iodide in a total volume of 1000 ml; and 0.1 N solution of sodium thiosulphate containing 24.823 gms per 1000 ml.

Procedure:

The thiosulphate solution should be standardized against the iodine solution adding the thiosulphate to 20 ml of the iodine solution until a pale yellow colour is reached. After the addition of a few drops of starch solution the titration is continued until the blue colour produced disappears.

Add to 10 ml of the material, 50 ml of 0.1 N solution of potassium iodide containing 16.6 gms in 1000 ml and titrate back the quantity of iodine liberated by the chlorine.

100 ml of 0.1 N potassium iodide is equivalent to 0.3545 gm chlorine.

8. **Determination of ammonium bifluoride (ABF) content in commercial ammonium bifluoride:***

Procedure:

8.1 **Quantitative Analysis:**

Weigh a watch glass covered with polythelene sheet. Weigh about 0.2 gm of ammonium bifluoride quickly (it is not necessary to take exactly 0.2 gm ABF since

* From Handbook of Cane Sugar Technology by R.B.L. Mathur, II Edn.

the actual weight is taken in the calculation). Say the weight of ABF is 'W'.

Transfer this into a white polyethylene beaker or bottle by washing it with a jet of distilled water.

Add 3-4 drops of phenolphthalein or methyl orange indicator.

Titrate with deci-normal sodium hydroxide ($\frac{N}{10}$ NaOH) till solution shows:

With phenolphthalein indicator - Pink colour

With methyl orange indicator - Yellow colour

This is the end point

Take the burette reading (V ml)

Calculation :

$$\% \text{ of ABF} = \frac{V \times 0.0057 \times 100}{W}$$

Note : This calculation is valid for an exactly decinormal solution. If the normality of sodium hydroxide is different then corresponding change in the gram equivalent of ABF must be made.

Thus 1 ml $\frac{N}{10}$ NaOH = 0.0057 gm ABF

1 ml $\frac{N}{5}$ NaOH = 0.014 gm ABF etc.

8.2 **Qualitative test for ammonium bifluoride:**

Fluoride ions of ABF combine with calcium of calcium chloride, to give a dense precipitate of calcium bifluoride.

$CaCl_2 + NH_4F.HF \rightarrow CaF_2 + NH_4Cl$

This reaction can also be used for quantitative estimation of ABF by the gravimetric method.

ABF has bleaching action. Thus it removes yellow colour of ferric chloride solution.

9. **Analysis of Commercial Formaline:**

Take one ml of formaline in a 100 ml measuring flask and make up the volume. Take 10 ml of the above solution in an iodine flask. Add 10 ml of distilled water into it. Add 50 ml of N/10 iodine solution and N/10 sodium hydroxide solution till it becomes light yellow. Let it remain as such for 10-15 minutes. Add dilute HCl solution till the whole

iodine is liberated. Titrate it against standard N/10 sodium thiosulphate solution using starch as an indicator. End point is the disappearing of violet colour formed by starch. A blank test is to be done in the same way as above but without adding the sample solution. The difference between the blank and the sample reading is the amount of the oxidizing solution used for oxidizing formaldehyde.

Calculation:

Since, 1 ml N/10 $Na_2S_2O_3$ = 1.5 mg HCHO

Then, per cent Formaline in commercial product

= Difference between blank and sample reading x 1.5

METHODS OF CHEMICAL ANALYSIS OF VARIOUS PROCESS CHEMICALS AS PER BUREAU OF INDIAN STANDARDS :

METHOD OF TEST FOR LIME STONE
(as per IS: 1760 - 1962)

1. **Determination of Loss on Ignition**

1.1 Weigh exactly one gram of the test sample into a previously weighed platinum crucible. Heat gently at first, then at a gradually increasing temperature. Finally ignite at 900° to 950°C for half an hour and raise the temperature to 1100°C, keep for about 10 to 15 minutes, cool and weigh. Repeat heating, cooling and weighing till constant weight is obtained Difference in weight represents loss on ignition.

1.2 *Calculation*

$$\text{Loss on ignition, percent} = \frac{(A-B)}{C} \times 100$$

Where

A = initial weight in g of the crucible with the sample

B = final weight in g of the crucible with the residue after ignition, and

C = weight in g of the sample taken.

2. **Determination of Silica by the Gravimetric method**

2.1 Outline of the Method - A known weight of the sample is dissolved in dilute hydrochloric acid and the solution is set for drying and baking. The baked mass is extracted with dilute hydrochloric acid. The insoluble residue left over is then fused with anhydrous sodium carbonate and the melt is extracted with dilute hydrochloric acid. The silica is dehydrated and determined by hydrofluorization.

2.2 *Reagents*

2.2.1 Dilute Hydrochloric Acid - 40 percent (v/v).

2.2.2 Fusion Mixture - Mix carbonates of sodium and potassium in equal proportion.

2.2.3 Dilute Sulphuric Acid - 1:4 and 1:1 (v/v).

2.2.4 Hydrofluoric Acid - 40 percent

2.3 *Procedure (For other than Magnesite Refractory Materials)*

2.3.1 Weigh accurately 2.5 g of the test sample into a beaker or a porcelain dish and add to it 40 to 50 ml of dilute hydrochloric acid, covering the beaker by means of a suitable cover glass immediately after addition of the acid. As soon as effervescence stops, wash the lower surface of the cover glass into the beaker and set the contents for drying and baking at 110^0 to 115^0C. After baking for about 20 to 25 minutes, cool to room temperature add 25 to 30 ml of dilute hydrochloric acid, boil and filter. Transfer thoroughly, to the filter, all the residue in the beaker as well as that adhering to the sides of the beaker, by hot water. Wash the filter free from chloride by means of hot water. Collect the filtrate and washings in the same beaker and preserve it.

2.3.2 Transfer the filter with its residue into a previously heated platinum crucible and smoke off the filter paper at a low heat without letting the paper take fire. Finally ignite at 900^0 to 950^0C until a constant weight of a perfectly white precipitate is obtained. For all practical purposes this shall be reported as 'Insoluble residue'. For very accurate determination of silica the procedure as given under 2.3.3. to 2.3.5. shall be followed.

2.3.3 Fuse the 'insoluble residue' in the platinum crucible with about 3 g of fusion mixture. Cool and extract the melt in about 50 ml of dilute hydrochloric acid. Mix with the filtrate from 3.1 and repeat the process of baking and drying. Extract the baked mass with about 30 to 40 ml of dilute hydrochloric acid and filter. Transfer all the silica in the beaker to the filter thoroughly by means of hot water. Wash silica on the filter free from chloride by means of hot water. Collect the filtrate and washings in the same beaker and preserve the filtrate.

2.3.4 Transfer the filter with its residue into a previously heated platinum crucible and smoke off the filter paper at a low heat without burning the paper. Finally ignite at 900^0 to 950^0C until a constant weight of a perfectly white precipitate is obtained. Now moisten the residue of silica with few milliliters of dilute sulphuric acid (1:1) and add to it about 10 ml of hydrofluoric acid. Evaporate to dryness; ignite, cool and weigh.

2.3.5 Carry out a blank determination following the same procedure and using the same amounts of the reagents but without the sample.

2.3.6 Preparation of the Main Solution - Fuse the residue left over in the platinum crucible after volatilization of silica thoroughly with one to two grams of fusion mixture and add the extract in dilute hydrochloric acid to the filtrate reserved under 2.3.3. Mix these combined filtrates with that reserved under 2.3.1 and treat this as final filtrate. Transfer the final filtrate to 250-ml measuring flask and make up to the mark. (If filtrate is bulky, it should be

concentrated to 250 ml by boiling.) Suitable aliquots of this solution referred to as main solution, shall be used.

2.3.7 *Calculation :*

$$\text{Silica, percent} = [\frac{(A - B) - C}{D}] \times 100 + E$$

Where

A = weight in g of platinum crucible with residue of silica before volatilization.

B = weight in g of platinum crucible with residue, if any, obtained after repeated volatilization.

C = weight in g of silica obtained in blank determination :

D = weight in g of the sample taken.

E = silica, percent as obtained under 7.3.3; and

2.4 Procedure (for Magnesite Refractory Materials)

2.4.1 Weigh one gram of the sample in a platinum crucible or porcelain dish and fuse it with 6 to 8 g of pure anhydrous sodium carbonate. Extract the melt carefully with 40 to 50 ml of dilute hydrochloric acid in a 500 ml beaker and when dissolution is complete, wash the crucible thoroughly with hot water. Evaporate the solution to dryness on a hot-plate and bake for about 20 minutes.

2.4.2 Cool the beaker, add 25 to 30 ml of dilute hydrochloric acid, boil and filter. Transfer thoroughly all the residue in the beaker to the filter by a jet of hot water and wash it free from acid by means of hot water. Collect the filtrate and washings in the same beaker and preserve it. Further, complete the estimation as described under 2.3.2. to 2.3.7.

3. Determination of Alumina

3.1 Outline of the Method - In a suitable aliquot of the main solution, ferrous iron is oxidized, and mixed oxides are precipitated, filtered, ignited and weighed as R_2O_3. The residue is fused with potassium pyrosulphate and extracted with sodium potassium tartarate solution. Alumina is precipitated from the acetate solution as 8-hydroxyquinoline complex (oxinate), filtered, dried and weighed. Alternatively, alumina is determined by subtracing the weight of iron oxide estimated separately from the total weight of mixed oxides.

3.2 Reagents

3.2.1 Concentrated Nitric Acid - sp-gr 1.42 (conforming to IS : 264-1950 Specification for Nitric Acid).

3.2.2 Concentrated Ammonium Hydroxide - sp-gr 0.90

3.2.3 Ammonium Nitrate Solution - one percent (w/v).

3.2.4 Methyl Red Indicator Solution - 0.4 g/l. Dissolve 0.1 g of methyl red in 3.72 ml of sodium hydroxide solution (0.1 N) and dilute to 250 ml with water. Filter, if necessary.

3.2.5 Ammonium Chloride Wash Solution - Dilute 25 ml of hydrocholoric acid, neutralize to methyl red with concentrated ammonium hydroxide and dilute to one litre. Add two drops in excess of concentrated ammonium hydroxide.

3.2.6 Concentrated Hydrochloric Acid - sp-gr 1.16 (conforming to IS : 265-1950 Specification for Hydrochloric Acid.)

3.2.7 Sodium Potassium Tartarate Solution - 20 percent (w/v).

3.2.8 Hydrogen Sulphide - Gas.

3.2.9 Ammonium Sulphide Wash Solution - Add 5 g of ammonium chloride to ammonium sulphide solution (5 percent).

3.2.10 8-Hydroxyquinoline (Oxine) Solution - Dissolve 5 g of oxine in 15 ml of acetic acid by warming and dilute to 250 ml.

3.3 **Procedure (By the Oxine Method)**

3.3.1 Take 100 ml of the main solution, add 2 to 3 ml of concentrated nitric acid to oxidize ferrous iron and boil. From the boiling solution precipitate mixed oxides by adding concentrated ammonium hydroxide in presence of ammonium chloride, carefully, using methyl red as indicator until the colour changes to a distinct yellow. Allow to settle, filter and wash four times with hot ammonium chloride wash solution. Preserve the filtrate and washings.

3.3.2 Return the precipitate to the beaker and dissolve by heating with 10 ml of concentrated hydrochloric acid and some water. Dilute, heat to boiling and precipitate as before. Filter, and wash well with hot ammonium nitrate solution. Mix the filtrate with that reserved under 3.3.1. Reduce the bulk by evaporation, cool, transfer to a 250-ml measuring or volumetric flask, make up to the mark and use aliquots of this solution for the determination of calcium oxide and magnesia.

3.3.3 Place the precipitate in a weighed platinum crucible. Dry ignite carefully, at first, finally heat to 1000°C for an hour, cool and weigh. Carry out a blank determination and correct for this value. Record the net weight which represents mixed oxides of iron and alumina. Hydrofluorize the R_2O_3 residue and determine the loss in weight which represents silica. Add the resultant Figure in percent to silica content obtained under 2.3.

3.3.4 Fuse the residue left after hydrofluorization of R_2O_3 with potassium pyrosulphate in a platinum crucible. Add 25 ml of sodium potassium tartarte solution : make strongly ammoniacal and pass hydrogen sulphide gas for about 10 minutes. Allow to settle filter and wash with weak ammonium sulphide wash solution. Preserve the residue. Boil the filtrate which contains all alumina and is free from iron, to expel most of the ammonium sulphide, then acidify with concentrated hydrochloric acid and boil down to nearly 100 ml. Filter the precipitated sulphur, wash and carefully neutralize the excess acid in the filtrate with concentrated ammonium hydroxide and bring back to acid reaction with one or two drops of concentrated hydrochloric acid, using methyl red as indicator. Dilute to approximately 200 ml, heat to 70^0 to 80^0C and add 25 ml of oxine solution followed by 25 ml of ammonium acetate solution. Stir and cool to room temperature. Allow to stand for several hours or preferably overnight; filter and wash the precipitate with water at room temperature, and dry it at 130^0 to 140^0C to constant weight and weigh it as Al $(C_9H_6ON)_3$.

3.3.5 Calculation

$$\text{Alumina, percent} = \frac{A \times 0.1110}{B} \times 100$$

Where

A = weight in g of the oxinate precipitate, and

B = weight in g of the sample represented by the aliquot taken.

3.4 Procedure [By the Difference (Alternate) Method] - Subtract from the net weight of mixed oxides as obtained under 7.3.3 the calculated weight of ferric oxide, and the amount of silica as obtained under 3.3.3 and 4.4.2 respectively.

4. Determination of Ferric Oxide

4.1 Outline of the Method - From an aliquot of the main solution mixed oxides are precipitated, filtered and ignited. The ignited mixed oxides are fused with an alkali bisulphate and the fused mass extracted with sulphuric acid. After the removal of silica iron in the filtrate is determined by comparing the intensity of red colour produced by the addition of potassium thiocyanate to the filtrate with that produced in a reference standard. Alternatively, when iron content is high, iron is determined volumetrically by titration with standard potassium permanganate solution.

4.2 Reagents

4.2.1 Potassium or Sodium Bisulphate - solid.

4.2.2 Potassium Thiocyanate Solution - Dissolve 97 g of potassium thiocyanate in 200 ml of water and dilute to one litre.

4.2.3 Standard Iron Solution - (1ml = 0.000 1 g of Fe_2O_3) - Dissolve 0.7024 g of ferrous ammonium sulphate in water, add 5 ml of concentrated sulphuric acid and oxidize with bromine water. Boil to expel excess bromine, cool and make up to one litre.

4.2.4 Buffer Solution - Weigh 0.05 g of pure alumina prepared by igniting ammonium alum in a platinum dish, and fuse it with 5 g of potassium bisulphate. Extract the cold cake with water, add 10 ml of concentrated sulphuric acid and make up to one litre. This solution acts as a buffer to counteract the effect of the aluminium sulphate in the test solution on the tint of the ferric thiocyanate.

4.2.5 Stannous Chloride Solution - Dissolve by heating 60 g of pure stannous chloride in a mixture of 400 ml concentrated hydrochloric acid and 600 ml of water until the solution is complete. Cool, add a few pieces of granulated tin and preserve the solution in an air-tight amber-coloured bottle.

4.2.6 Mercuric Chloride Solution - saturated.

4.2.7 Zimmermann - Reinhardt Solution - Add 140 ml of concentrated sulphuric acid and 140 ml of syrupy phosphoric acid to 720 ml of water. Dissolve 200 g of hydrated manganese sulphate in this solution while this solution is still hot, add dropwise, potassium permanganate solution (0.02 N) with stirring until the persistent pink color is obtained.

4.2.8 Standard Potassium Permanganate Solution - 0.02 N. Dissolve 0.63 of potassium permanganate in one litre of water. Keep the solution in glass-stoppered amber-coloured bottle for 5 to 6 days. Filter through glass wool into a clean glass- stoppered bottle and standardize against sodium oxalate (AR).

4.3 **Procedure** (By the Colorimetric Method for Iron Content <= 0.5 percent)

4.3.1 Take 100 ml of the main solution, precipitate mixed oxides as described under 3.3.1. and 3.3.2 and ignite as under 3.3.3. Fuse the ignited oxides and mixed oxides very slowly in a platinum crucible with potassium pyrosulphate. Detach the melt when cold and transfer to a porcelain basin adding about 150 ml of water and 20 ml of concentrated sulphuric acid. Rinse the crucible with water and pour the washings into the basin. Heat the mixture slowly over a hot-plate or a water-bath until the entire melt is dissolved. Cool, filter off any silica and wash with hot water. Determine the silica content. Add the resultant figure in percent to that of silica content obtained under 2.3. Pour the solution after cooling into a 250-ml measuring flask and make up to the mark with cold water. This constitutes stock solution.

4.3.2 Dilute an aliquot portion of the stock solution to 250 ml in a measuring flask and use this as test solution. Dilute 5 ml of the standard iron solution to 100 ml in a measuring flask and transfer to a burette reading to 0-1 ml and

fill a similar burette with water. Fill two colorimeter test cells; one with 10 ml of potassium thiocyanate solution together with 10 ml of potash alum solution and the other with 10 ml of potassium thiocyanate solution teogether with 10 ml of test solution. Add the standard iron solution from the burette to the former and equal amount of water from the other burette to the latter, stirring thoroughly, until the tints in the two test cells match approximately. Compare the intensities of colours in a suitable type of colorimeter.

4.3.3 Calculation :

$$\text{Ferric oxide, percent} = \frac{A}{B} X \frac{250}{C} x \frac{H_1}{H_2} x\ 0.0125$$

Where

A = volume in ml of dilute standard iron solution.

H_1 = height of column of dilute standard iron solution.

B = weight in g of the sample represented by the volume of the aliquot taken in 4.3.1

C = volume in ml of the aliquot taken from the stock solution in 4.3.2 and

H_2 = height of column of the test solution.

4.4 **Procedure** (By the Permanganate Method for Iron Content > 0.5 Percent)

4.4.1 Pipette out 100 ml of the main solution into a 500-ml conical flask. Heat to boiling and to the boiling solution, add stannous chloride solution dropwise with continuous stirring until the solution just becomes colourless. Add few drops of stannous chloride solution in excess and wash down the sides with a little water. Cool the contents to room temperature. Add excess of mercuric chloride solution. Keep for few minutes and add 20 to 30 ml of Zimmermann - Reinhardt solution and dilute to about 500 ml, washing down the sides of flask. Titrate immediately with standard permanganate solution causes a pink colouration stable for four to five seconds.

4.4.2 Calculation :

$$\text{Ferric oxide, percent} = \frac{A \times B \times 0.07984 \times 100}{C}$$

Where

A = volume in ml of the standard permanganate solution consumed.

B = normality of the standard permanganate solution and

C = weight in g of the sample represented by the aliquot taken.

5. **Determination of Calcium Oxide by the Oxalate method (Applicable to minerals other than Magnesite)**

5.1 Outline of the Method - Calcium is precipitated as its oxalate by ammonium oxalate from boiling solution in presence if ammonium chloride and acetic acid. The precipitate is filtered, washed, dissolved in hot dilute hydrochloric acid and reprecipitated. This precipitate is filtered, washed dissolved in hot sulphuric acid and titrated against standard potassium permanganate solution to slight pink colour.

5.2 **Reagents :**

5.2.1 Ammonium Chloride - solid.

5.2.2 Dilute Hydrochloric Acid - 1:1 (v/v).

5.2.3 Concentrated Ammonium Hrdroxide - sp-gr 0.90

5.2.4 Acetic Acid - glacial

5.2.5 Ammonium Oxalate Solution - saturated.

5.2.6 Ammonium Oxalate Solution - 2 percent (w/v).

5.2.7 Oxalic Acid Solution -1 g/1 (w/v).

5.2.8 Dilute Sulphuric Acid - 1 : 4 (v/v).

5.2.9 Standard Potassium Permanganate Solution - 0.1N. Dissolve 3.20 g of pure potassium permanganate in one litre of water. Keep the solution in glass-stoppered dark-coloured bottle for a week before use. Filter it then through glass wool or asbestos into another glass-stoppered dark-coloured bottle and standardize against oxalic acid (AR) or sodium oxalate (AR).

5.3 **Procedure**

5.3.1 Pipette out exactly 50 ml from the filtrate reserved under 3.3.2 and transfer to a 500 ml beaker. Add sufficient ammonium chloride (about 20 to 25 g) to hold magnesium in solution in presence of ammonium oxalate. (It is recommended to add about 10 g of ammonium chloride per 0.001 5 g of magnesia for 100 ml of solution). Generally, sufficient ammonium chloride is obtained by adding about 20ml of dilute hydrochloric acid and neutralizing with concentrated ammonium hydroxide. Add 20 ml of dilute acetic acid, heat to boiling and add with stirring about 10 to 15 ml of saturated solution of ammonium oxalate. Finally, add a slight excess of ammonium oxalate solution. Allow the precipitate to settle for one to two hours on a water-bath, cool and filter, Wash the precipitate with water at room temperature till free from oxalate. Preserve the filtrate and the washings.

5.3.2 Wash the precipitate into the same beaker in which precipitation was first carried out by making a perforation in the filter paper and dissolving in

about 50 ml of hot dilute hydrochloric acid poured through the filter in order to dissolve any adhering precipitate. Finally wash the filter thoroughly with hot water till the filter is free from acid and collect the washings also in the same beaker into which the precipitate was transferred. Reduce the bulk to about 100 ml by evaporation and reprecipitate calcium as its oxalate by the procedure described under 5.3.1.

5.3.3 Filter the precipitate and wash first with hot water containing oxalic acid or ammonium oxalate and then with hot water till the final runnings are free from oxalate or oxalic acid. Collect the filtrate and washings. Mix this filtrate with the filtrate reserved under 5.3.1. Concentrate the solution to about 100 ml and preserve for the determination of magnesia.

5.3.4 Wash the precipitate of calcium oxalate into the same beaker in which precipitation was first carried out by making a perforation in the filter paper and treat the-filtrate with about 25 ml of warm (70^0 to 80^0C) dilute sulphuric acid for dissolving adhering precipitate of calcium oxalate. Wash the filter free from acid by means of hot water. Collect the washings also in the same beaker into which the precipitate was transferred. Add about 25 ml more of dilute sulphuric acid and raise the temperature of contents to about 70^0C. When the precipitate has dissolved, titrate with standard potassium permanganate solution till a permanent pink colour persists.

5.4 **Calculation**

$$\text{Calcium oxide, percent} = \frac{\text{A X B X 5X 0.028}}{\text{C}} x100$$

Where

A = volume in ml of the standard permanganate solution.

B = normality of the standard permanganate solution, and

C = weight in g of the sample represented by the aliquot taken.

6. Determination of Magnesium Oxide by the Pyrophosphate method (Applicable to Dolomite and Limestone)

6.1 Outline of the Method - The filtrate from calcium determination is evaporated to almost dryness and ammonium salts are expelled. The dry mass is extracted in dilute hydrochloric acid, boiled and filtered. From the cold acid filtrate, magnesium is precipitated as magnesium ammonium phosphate. The precipitate is filtered, ignited and weighed as magnesium pyrophosphate.

6.2 **Reagents**

6.2.1 Concentrated Nitric Acid - see 3.2.1

6.2.2 Dilute Hydrochloric Acid - 1:3 (v/v.)

6.2.3 Diammonium Phosphate Solution - 10 percent solution (w/v).

6.2.4 Methyl Red Indicator Solution - see 3.2.4.

6.2.5 Concentrated Ammonium Hydroxide - sp-gr 0.90

6.2.6 Ammonium Hydroxide Wash Solution - 1 :20 (v/v).

6.2.7 Silver Nitrate Solution - 0.1 percent (w/v).

6.3 **Procedure**

6.3.1 Evaporate the filtrate reserved under 5.3.3 on a hot-plate. When the contents in the beaker attain syrupy consistency, take out the beaker, cool and add about 50 to 60 ml of concentrated nitric acid, cover the beaker immediately by a cover glass and set it for boiling and evaporate once again on a hot-plate. Take out the watch-glass when the vigorous evolution of gases has ceased. Wash the lower surface of watch-glass into the beaker and evaporate the liquid to dryness. As soon as all the liquid has been driven off and the residue becomes dry, cool and repeat addition of concentrated nitric acid and evaporate to dryness once again to ensure complete expulsion of ammonium salts. Now, after second evaporation, add about 30 to 40 ml of dilute hydrochloric acid, boil and filter. Wash the filter free from chloride by means of hot water collecting the filtrate and washings in the same beaker. Discard the residue and reduce the bulk of the filtrate and washings by evaporation to about 100 ml. Cool well and add about 25 to 30 ml of diammonium phosphate solution. Add a few drops of methyl red indicator solution and add slowly with constant stirring concentrated ammonium hydroxide till the solution is just alkaline. Add further 15 to 20 ml of concentrated ammonium hydroxide for every 100 ml of the solution and stir vigorously with a rubber-tipped glass rod for about 10 minutes to start the precipitation. Continue stirring until there is no further visible precipitation. Let the solution stand for at least six hours or preferably overnight.

6.3.2 Filter the precipitate and wash with dilute ammonium hydroxide until a few drops of the washing, after being acidified with nitric acid, give no opalescence with silver nitrate solution. Wash the precipitate back into the beaker in which it was first precipitated. Dissolve the precipitate in about 30 ml of hot dilute hydrochloric acid and dilute to about 100 ml, and reprecipitate magnesium ammonium phosphate as described under 6.3.1. Filter and wash the precipitate with dilute ammonium hydroxide solution discarding the filtrate and the washings. Dry the paper and the precipitate, in a weighed porcelain or silica crucible, clear the paper slowly without allowing it to ignite and burn the carbon over a gradually increased flame which never heats the crucible more than faintest red. Finally, ignite for 30 minutes at about 1000^0 C to constant weight.

6.4 **Calculation**

$$\text{Magnesia, percent} = \frac{AX0.3621X5}{B} X100$$

Where

A = weight in g of magnesium pyrophosphate obtained in the test, and

B = weight in g of the sample represented by the aliquot used.

7. **Determination of Calcium and Magnesium Oxides in Magnesite by the Phosphate method (Applicable to Magnesite)**

7.1 Outline of the Method - From the solution containing calcium and magnesium, both the ions are precipitated together as their phosphates. The precipitate is filtered, ignited and weighed. The weighed precipitate is dissolved in sulphuric acid and evaporated to fumes. The calcium sulphate is precipated, dried, dissolved in dilute hydrochloric acid and precipitated as oxalate in acetic acid medium. Calcium oxalate is then dissolved in sulphuric acid and titrate with standard permanganate solution.

7.2 **Reagents -** In addition to the reagents given under 6.2. the following reagents are also required.

7.2.1 Dilute Sulphuric Acid - 1 : 4 and 1 : 19 (v/v).

7.2.2 Alcohol - 75 percent (v/v).

7.2.3 Concentrated Ammonium Hydroxide - sp-gr 0.90

7.2.4 Dilute Acetic Acid 1 :2 (v/v).

7.2.5 Ammonium Oxalate Solution - 2 percent (w/v).

7.2.6 Standard Potassium Permanganate Solution - 0-02 N (see 4.2.8)

7.3. **Procedure**

7.3.1 Pipette out exactly 50 ml from the filtrate reserved under 3.3.2 into a 500-ml beaker and obtain the ignited residue of mixed phosphates by following procedures described under 6.3.1 and 6.3.2 and weigh as $[Ca_3(PO_4)_2+Mg_2P_2O_7]$.

7.3.2 Transfer the weighed precipitate to small beaker and dissolve it in a little dilute sulphuric acid, avoiding more that approximately

0-5 ml in excess. In case the precipitate dissolves with difficulty, boil it with concentrated nitric acid and evaporate until copious fumes of sulphuric acid appear. Add 100 ml of alcohol for every 0-3 g of pyrophosphate originally present and allow the solution to stand for several hours or preferably

overnight. Filter, wash the residue of calcium sulphate with alcohol, and dry the precipitate. Dissolve it in very little dilute hydrochloric acid and neutralize with ammonia. Precipitate calcium oxalate in acetic acid medium by means of ammonium oxalate as under 5.3.1.

7.3.3 Transfer the precipitate back to the beaker in which calcium was precipitated by puncturing the filter paper and washing down the adhering precipitate with 10 to 15 ml of dilute sulphuric acid (1 : 19) and finally with a jet of hot water. Add about 100 ml of dilute sulphuric acid to the solution. Heat at 75^0 to 80^0 C and titrate immediately with standard permanganate solution.

7.4 **Calculation**

7.4.1 Calcium Oxide, D, percent $= \frac{AXBX5X0.028}{C} X100$

Where

A = volume in ml of the standard permanganate solution consumed.

B = normality of the standard permanganate solution, and

C = weight in g of the sample represented by the aliquot taken from the main solution for R_2O_3 precipitation.

7.4.2 Magnesia, percent $= \frac{(E-F)X5X0.3621}{C} X100$

Where

E = weight of the residue of mixed phosphates $[Ca_2(PO_4)_2+Mg_2P_2O_7]$, and

F = weight in g of calcium phosphate $[Ca_3 (PO_4)_2]$ = C x D x 0.018 43.

8. **Determination of Magnesium Oxide by the Oxide method (Applicable to Calcite)**

8.1 Outline of the Method - The filtrate from the calcium determination is evaporated to almost dryness and ammonium salts are expelled. The dry mass is extracted is hydrochloric acid, boiled and filtered. From the alkaline filtrate, in presence of little ammonium chloride, magnesium is precipitated with 8-hydroxyquinoline, filtered, dried and weighed.

8.2 **Reagents**

8.2.1 Concentrated Nitric acid - see 3.2.1.

8.2.2 Dilute Hydrochloric Acid - 1: 3 (v/v).

8.2.3 Ammonium Chloride Solution - 10 percent (w/v).

8.2.4 Dilute Ammonium Hydroxide - Dilute 200 ml of concentrated ammonium hydroxide (sp-gr 0.90) to 500 ml with water.

8.2.5 8-Hydroxyquinoline (Oxine) Solution - Titrate 2.5 g of 8-hydroxyquinoline with 5 ml of glacial acetic acid and make up to 100 ml with hot water.

8.2.6 O-Cresolpthalein Indicator Solution - 0.2 percent solution in alcohol.

8.2.7 Ammonium Hydroxide Wash Solution - 1 : 40 (v/v).

8.3 **Procedure**

8.3.1 Evaporate the filtrate reserved under 5.3.3 to syrupy consistency and expel all ammonium salts. Dissolve the residue in concentrated hydrochloric acid, heat to boiling, filter and wash free from acid as described under 6.3.1.

8.3.2 Now add to the clear filtrate 10 ml ammonium chloride solution and 0.5ml of O-cresolphthalein indicator solution. Neutralize with dilute ammonium hydroxide solution until a violet colour is obtained (pH about 9.5) and then add 2 ml of the ammonia solution in excess. Heat to 70^0 to 80^0 C, add oxine solution very slowly and with constant stirring until a small excess is present as shown by the deep yellow colour of the supernatant liquid. Avoid a large excess of the precipitant, as the reagent itself may precipitate. Digest the precipitate on the steam-bath for 10 minutes with frequent stirring and collect the precipitate on a weighed sintered glass crucible. Wash the precipitate with ammonium hydroxide wash solution, dry to constant weight at 155^0 to 160^0C and weigh as the anhydrous compound Mg $(C_9H_6\ ON)_2$.

8.4 **Calculation**

$$\text{Magnesia, percent} = \frac{A \times 0.1291 \times 5}{B} \times 100$$

Where

A = weight in g of the oxinate obtained, and

B = weight in g of the sample represented by the aliquot taken.

9. **Determination of Carbon Dioxide**

9.1 **Outline of the Method** - A known weight of the sample is made to react with an acid and the liberated carbon dioxide freed from impurities is absorbed in previously weighed soda asbestos bulbs and weighed. From the difference in weights the percentage of carbon dioxide is calculated.

9.2 **Apparatus** - The assembly of apparatus is shown in Fig. 1 in order to obtain better pressure for drawing gases through the train, all joints should be mercury sealed.

9.3 **Reagents**

9.3.1 Dilute Hydrochloric Acid - 1 :1 (v/v).

9.3.2 Concentrated Sulphuric Acid - sp-gr 1.84 (conforming to IS : 266-1957 Specification for Sulphuric Acid.)

9.3.3 Ascurite or Soda Asbestos

9.3.4 Magnesium Perchlorate - Solid

9.3.5 Pumice Impregnated with Copper Sulphate - Anhydrous. Crush pumice to approximately 5 mm size, sift free from dust, and transfer 60 g to a casserole. Cover with a concentrated solution of 30 to 35 g of copper sulphate, evaporate to dryness while constantly stirring, and then heat for 3 to 4 hours at 150^0 to 160^0 C in an air-bath. Cool in a desiccator and preserve in a glass-stoppered bottle.

9.4 **Procedure**

9.4.1 Transfer one gram of the accurately weighed sample to the flask A and cover it with water. Insert the stopper carrying the separatory funnel B and a condenser C. Connect the latter with D.E and F. Pass air that is free from carbon dioxide through the system until it is judged that all carbon dioxide has been removed. Close the stop-cock in the separatory funnel, and insert the weighed absorption bulbs G and H in the train; the latter cats as a guard tube. Half fill the separatory funnel with dilute hydrochloric acid, replace the stopper carrying the air, and see that there is free passage for gases through the train. Open the stop-cock in the separatory funnel and run acid into the flask slowly if there is much carbon dioxide, and rapidly if there is but little. When effervescence diminishes in the former case, at once in the latter, start a flow of water in the condenser, and heat the flask slowly so as to secure steady but quiet ebullition. When it is judged that carbon dioxide has been boiled out of the solution, remove the flame, increase the current of air and sweep out all carbon dioxide. Disconnect the weighed bulbs, close the inlet and outlet tubes, and place them in the balance case. When cool, open the stopper momentarily, and weigh.

9.5 **Calculation**

$$\text{Carbon dioxide, percent} = \frac{(B - A)}{C} \times 100$$

Where

B = weight in g of the bulbs after the test.

A = weight in g of the bulbs before the test, and

C = weight in g of sample taken.

METHOD OF TEST FOR PHOSPHORIC ACID

(as per IS : 10508 - 1983)

A.1 **Purity**

A.1.1 Weigh 1.000 g of phosphoric acid into a glass-stoppered flask, dilute with about 100 ml of water, add 0.5 ml of thymolphthalein solution. (Dissolve 0.100 g of thymolphthalein in 100 ml of ethanol and filter, if necessary). Titrate with N sodium hydroxide. Each millilitre of N sodium hydroxide is equivalent to 0.049 g of H_3PO_4.

A.2 **Fluoride**

A.2.1 Apparatus

A-2.1.1 Assembly as shown in Fig. 13.

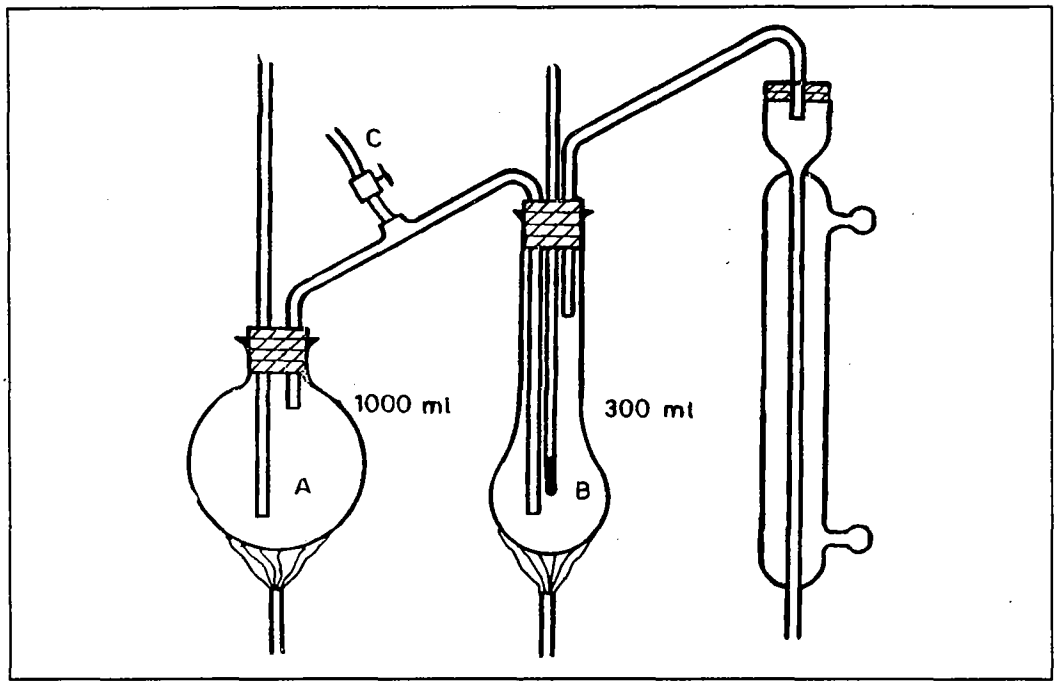

Fig. 13 : Apparatus for Limit Test for Fluoride

A.2.2 Reagents

A.2.2.1 Phenolphthalein Solution - Dissolve 0.2 g of phenolphthalein in 60 ml of 90 percent ethanol and add sufficient water to make 100 ml.

A.2.2.2 Sodium Hydroxide - N.

A.2.2.3 Sulphuric Acid - Concentrated.

A.2.2.4 Sodium Fluoride Solution - Containing 50 µg of fluorine.

A.2.2.5 Hydrochloric Acid - 4 N.

A.2.2.6 Zirconium Alizarin Solution - Dissolve 0.80 g of zirconium nitrate in water, add a few drops of 4 N nitric acid, and make up to 100 ml with water. Dissolve 0.10 g of alizarin sulphonate monohydrate in 20 ml of water, and make up to 100 ml with ethanol. Mix 1 ml of first solution with 1 ml of the second solution and add 18 ml of water. This solution should be clear and the dilution should be freshly prepared.

A.3 **Procedure**

A.3.3.1 Place about 500 ml of water in flask A (Fig. 13), make it alkaline to phenolphthalein solution with N sodium hydroxide and heat the water to boiling. Leave open the screw clamp at C.

A.3.3.2 Determine the appropriate mass of the sample (M, in grams) by the formula M = 50/L, in which L is the fluoride limit, in mg/kg. Accurately weigh the calculated amount of the sample, place it in flask B, and add 10 ml of water to the flask. Add 17 ml of sulphuric acid slowly down the sides of the flask so that it forms a layer under the water. Connect flask B to the apparatus. Place the tip of the condenser into a flask containing 5 ml of water. Mix the contents of flask B, heat to 150°C and slowly shut the screw clamp at C. Regular the temperature of the solution in the flask B to 150-153°C during the distillation. Continue until 70 ml of distillate have been collected.

A.3.3.3 Place the distillate in a 100-ml Nessler tube. Place 80 ml of sodim fluoride solution, containing 50 µg of fluorine, in a second Nessler tube. To each tube add 8.5ml of 4N hydrochloric acid and 2.0 ml of zirconium-alizarin solution and make up to 100 ml with water. Let the tubes stand for 15 minutes.

A.3.3.4 The colour of the rest solution containing the sample shall not be darker than that of the standard solution.

A.4 **Heavy Metals**

A.4.1 Reagents

A.4.1.1 Ammonia Solution - Dilute 400 ml of ammonium hydroxide (28 percent) to 1,000 ml with water.

A.4.1.2 Hydrochloric Acid - 10 percent.

A.4.1.3 Lead Nitrate Stock Solution - Dissolve 159.8 mg of lead nitrate in 100 ml of water containing 1 ml of nitric acid. Dilute with water to 1000 ml and mix. Prepare and store the solution in lead-free glass containers.

A.4.1.4 Standard Lead Solution - Dilute 10 ml of lead nitrate stock solution accurately measured, with water to 100 ml. Each ml of the solution so prepared contains the equivalent of 10 mg of lead ions (Pb). Prepare the solution on the day of use.

A.4.1.5 Nitric Acid - 10 percent

A.4.1.6 Sulphuric Acid - 94.5 to 95.5 percent.

A.4.1.7 Acetic Acid - 6 percent.

A.4.1.8 Hydrogen Sulphide - A saturated solutions of hydrogen sulphide made by passing H_2S in cold water.

A.4.2 Procedure

A.4.2.1 Solution A - Take 2 ml of the standard lead solution in 50-ml Nessler tube and add 23 ml of water. Adjust the pH to between 3.0 to 4.0 by addition to acetic acid or ammonia solution. Dilute with water to 40 ml and mix.

A.4.2.2 Solution B - Place 2 g of the sample, accurately weighed in a suitable crucible, add sufficient nitric acid to wet the sample, and carefully, ignite at a low temperature until thoroughly charred, covering the crucible loosely with a suitable lid during the ignition. After the substance is thoroughly carbonized, add 2 ml of nitric acid and 5 drops of sulphuric acid and cautiously heat until white fumes are evolved. Then ignite, preferably in a muffle furnace, at 500^0 to 600^0C until the carbon is all burnt off. Cool, add 4 ml of dilute hydrochloric acid, cover and digest on a steam-bath for 10 to 15 minutes. Uncover, and slowly evaporate on a steam-bath to dryness. Moisten the residue with one drop of hydrochloric acid, add 10 ml of hot water and digest for 2 minutes. Add dropwise ammonia solution until the solution is just alkaline to litmus paper, dilute with water to 25 ml and adjust the pH to between 3.0 to 4.0 (pH indicator paper) by the addition of diluted acetic acid. Filter, if necessary, wash the crucible and the filter with 10 ml of water. Transfer to a 50-ml Nessler tube. Dilute the combined filtrate and washing with water to 40 ml and mix.

A.4.2.3 To each tube add 10 ml of freshly prepared hydrogen sulphide, mix and allow to stand for 45 minutes and view down over a white surface. The colour of Solution B shall not be darker than that of Solution A.

METHOD OF TEST FOR CAUSTIC SODA

(As per IS : 252 - 1973)

A.1 Quality of Reagents

A.1.1 Unless specified otherwise, pure chemicals and distilled water (see IS : 1070 -1960*) shall be used in tests.

Note - 'Pure chemicals' shall mean chemicals that do not contain impurities which affect the result of analysis.

A.2 **Prepared Sample Solution**

A.2.1 In a weighing bottle with a ground-glass stopper, weigh to the nearest 0.01 g, of the material (solid or liquid), equivalent to a little less than 50 g of caustic soda.

A.2.1.1 Solid Material - Dissolve the material (see A.2.1) in approximately 200 ml of water and cool it to room temperature; transfer the solution quantitatively to a 500-ml one-mark volumetric flask and dilute nearly to the mark, recool, then dilute to the mark and mix thoroughly. The solution thus prepared shall be used for the subsequent tests.

A.2.1.2 Liquid Material - Transfer the material (see A.2.1) directly to a 500-ml one mark volumetric flask and dilute nearly to the mark; cool to room temperature, then dilute to the mark and mix thoroughly.

A.3.1.1.2 Standard Hydrochloric Acid - 0.1 N

A.3.1.1.3 Methyl orange indicator solution - Dissolve 0.1 g of methyl orange in 100 ml of water.

A.3.1.1.4 Phenolphthalein Indicator Solution - Dissolve 0.1 g of phenolphthalein powder in 60 ml of rectified spirit (conforming to IS : 323 - 1959*) and dilute with water to 100 ml.

A.3.1.2 Procedure - Pipette out of 25 ml of the prepared sample solution (see A-2) into a conical flask and add 2 to 3 drops of phenolphthalein indicator. Titrate it against standard hydrochloric acid solution (1 N) up to a little before the end point. Take this reading as A. Further titrate it against standard hydrochloric acid (0.1 N) till the pink colour just disappears. Take this reading as B. Then add 2 to 3 drops of methyl orange indicator and continue titration against standard hydrochloric acid (0.1N) to a reddish orange colour. Take this reading as C.

A.3.1.3 Calculation

$$\text{carbonates (as } Na_2CO_3) \quad = \frac{212\,(C-B)\,X\,N}{M}$$

percent by mass

Where

N = normality of standard hydrochloric acid (0.1 N), and

M =mass of the material taken for test.

A.3.2 Method B (Gaseometric Method)

A.3.2.0 Principle - Measurement of the volume of carbon dioxide evolved from a portion of the test sample by reaction with a hydrochloric acid solution.

A.3.2.1 Reagents

A.3.2.1.1 Distilled water, or water of equivalent purity, free from carbon dioxide at room temperature. Eliminate any carbon dioxide present either by boiling water for 10 minutes and cooling it in the absence of atmospheric carbon dioxide or, more simply, by bubbling air free from carbon dioxide through it for 15 minutes.

The air is freed from carbon dioxide by passing it through a column containing pellets of sodium hydroxide. Store it in the absence of atmospheric carbon dioxide.

A.3.2.1.2 Hydrochloric acid - 12 N

A.3.2.1.3 Sodium chloride, coloured acid solution - dissolve 26 g of sodium chloride in water. Add 5 ml of sulphuric acid solution (d = 1.83). Dilute it to 1000 ml, add a small amount of 0.05 percent methyl orange indicator solution and mix thoroughly.

A.3.2.1.4 Sodium hydroxide solution - 6 N.

A.3.2.2 Apparatus - Apparatus as assembled is shown in Fig. 1.

A.3.2.3 Procedure

A.3.2.3.1 Weigh, to the nearest 0.01 g the test sample (solid or lye) corresponding to approximately 10 g of caustic soda.

A.3.2.3.2 Preparation of the apparatus - Fill burette B of the apparatus with the coloured acid solution through levelling bottle F. Pour into absorber C some of the sodium hydroxide solution. (Renew this solution after 100 determinations). With burette B and absorber C filled up to cock R_1 and graduation mark *a* respectively, and cocks R_1 and R_2 closed, place the test portion in flask A and, in the case of solid material, dissolve it in approximately 30 ml of water. Dilute to approximately 40 ml so as to reduce the dead space to a volume slightly greater than 100 ml (volume above the level of the liquid in flask A plus the volume of condenser tube D up to cock R). Place in the flask three porcelain or glass balls, about 2 mm in diameter, and a few pieces of pumice having a total volume approximately equal to that of the balls. Stopper the flask and close cock R. Connect flask A with burette B through cock R_1 and lower the levelling bottle F. Check the tightness of the apparatus by appropriately handling the cocks and the levelling bottle.

A.3.2.3.3 Evolution and measurement of carbon dioxide - By means of a separating funnel, pour 35 ml of the hydrochloric acid solution into flask A taking care to avoid loss of gas. The acidity of the solution in the flask is thus approximately 2 N after the evolution of carbon dioxide. Heat the flask and maintain the solution at boiling point for 5 minutes while running cold water through the condenser. Then stop heating and add more of the coloured acid solution by means of the separating funnel, lowering the levelling bottle F still further to make the solution in the flask A rise in the condenser tube up to cock R_1. Then close the latter and wait for 5 minutes to allow the gas to reach the temperature of the water jacket. Measure the volume of gas V at atmospheric pressure P and at the temperature t of the water in the jacket. For this purpose move the levelling bottle F to bring the coloured acid solution to the same level both in the flask and in the burette B; read the volume of the latter. Adjust the cocks R_1 and R_2 so that burette B and absorber C are connected, then raise the levelling bottle F so that the gas is transferred.

A.4 **Determination of Sodium Hydroxide**

A.4.1 Reagents

A.4.1.1 Standard Hydrochloric Acid - 1 N.

A.4.1.2 Methyl Orange Indicator Solution - Dissolve 0.1 g of methyl orange in 100 ml of water.

A.4.2 Procedure

Transfer exactly 20 ml of the sample solution (see A-2) to a 500-ml conical flask. Add approximately 80 ml of water and 5 drops of methyl orange indicator solution and titrate it against standard hydrochloric acid until the colour of the indicator changes from yellow to orange.

A.4.3 Calculation

Total alkalinity, percent by mass, $$B = \frac{V \times N}{M} \times 99.9925$$

Where

V = volume in ml of standard hydrochloric acid solution used for titration.

N = normally of standard hydrochloric acid solution, and

M = mass in g of the material taken for the test.

Sodium hydroxide (as NaOH), $= B - (A \times \frac{40}{53})$

Percent by mass

Where

B = total alkalinity, and

A = carbon dioxide content (as $Na_2 CO_3$) as calculated in A.3.2.4.

CHAPTER – VI

BOILER WATER CONTROL

CHAPTER – VI

BOILER WATER CONTROL

1. Conditioning of Boiler-Water

The working of a boiler may be adversely affected by scale - formation, corrosion and steam entrainment. Scale-formation on heating surfaces may lead to weak spots in the boiler, causing bulging or bursting of tubes and also adversely affecting heat transmission and thereby lowering boiler efficiency.

Corrosion will cause uneven eating away of the boiler metal a condition known as 'pitting'.

Some of the common scale forming constituents are : silica, salts causing hardness of water and undissolved solids in the water and also oil and sugar which may be carried to boiler water along with the condensates.

Corrosion may be due to presence of hydrogen sulfide, carbon dioxide, oxygen, ammonia, sugar and oil.

Steam entrainment is caused by foaming and priming.

Foaming takes place due to the presence of organic matter and high concentration of suspended matter. Priming is caused if the concentration of solids, dissolved or precipitated, in the boiler water is high. The boiler solids may be carried over along with the steam to the prime movers i.e. steam engines and turbines and deposits built up in the engine cylinder may wear out the cylinder and piston and deposits on turbine blades may lead to imbalance, tripping and severe damage of the turbine.

Treatment of raw water

In order to safeguard the boiler against the above impediments, water used for the boilers must be treated suitably, so that the following constituents are within prescribed limits.

1.1 Silica :

Silica in raw water should not exceed 10.0 parts per million (ppm). If it does, the water should be demineralised in ion exchange plant with anion exchanger capable of removing silica besides the anions released by the cation exchanger.

1.2 Total dissolved solids (TDS) :

If TDS are upto 500 ppm, a softening unit with base exchange resins will do. If they exceed the above limit treat the water, after removal of its turbidity, in an ion-exchange plant.

1.3 **Hardness :**

(a) For bicarbonate hardness add NaOH. If bicarbonate content (M) is 160 ppm as $CaCO_3$, NaOH required will be (0.8 x 160) + 175 = 278 ppm.

(b) For non-alkaline hardness [Total hardness (TH) - Bicarbonate hardness (M)], add sodium hexa meta phosphate, $(NaPO_3)_6$,. If TH-M is 30 ppm then $(NaPO_3)_6$ to be added will be (30 x 2/3) + 50 = 70 ppm.

(c) Sulphate : The total of that already present in the water and additional quantity added through Na_2SO_4 should be about 300 ppm.

(d) Starch powder is added at the rate of 1.00 kg per 10,000 litres of water, to help coagulation and free flow of precipitated hardness.

2. **Treatment of boiler water :**

Internal treatment of the boiler water is carried out continuously by addition of chemicals into it through the feed line. For boilers upto 21.0 kg/cm^2 pressure, the conditions to be maintained in the feed water should be as follows :

2.1 pH : 10.0 - 11.0 by the addition of alkalies and trisodium phosphate.

2.2 Total dissolved solids (TDS) : 1500 - 3000 ppm, by frequent blowdown.

2.3 Methyl orange alkalinity : 150 - 250 ppm.

2.4 Hardness : Zero

2.5 Residual Phosphates : 30 - 50 ppm (To indicate that calcium & magnesium have been converted into non scaling form).

2.6 Residual Sulphites : 30 - 50 ppm (to indicate the elimination of dissolved oxygen)

2.7 Deaeration : Satisfactory deaeration should be done to remove dissolved oxygen.

2.8 Oil : This should not exceed 7.0 ppm.

2.9 Sugar : Should be totally absent.

Phosphates precipitate hardness and alkalies create necessary alkalinity to protect the boiler metal against corrosion. Trisodium phosphate also contributes to alkalinity. Sodium sulphite and hydrazine are - oxygen scavengers.

3. **Boiler water analysis**

Sampling

The sample for analysis should be drawn through a cooling coil of copper so that no concentration takes place due to flashing. It should be cooled to room temperature. Sketch of a sampler is given in Fig. 14.

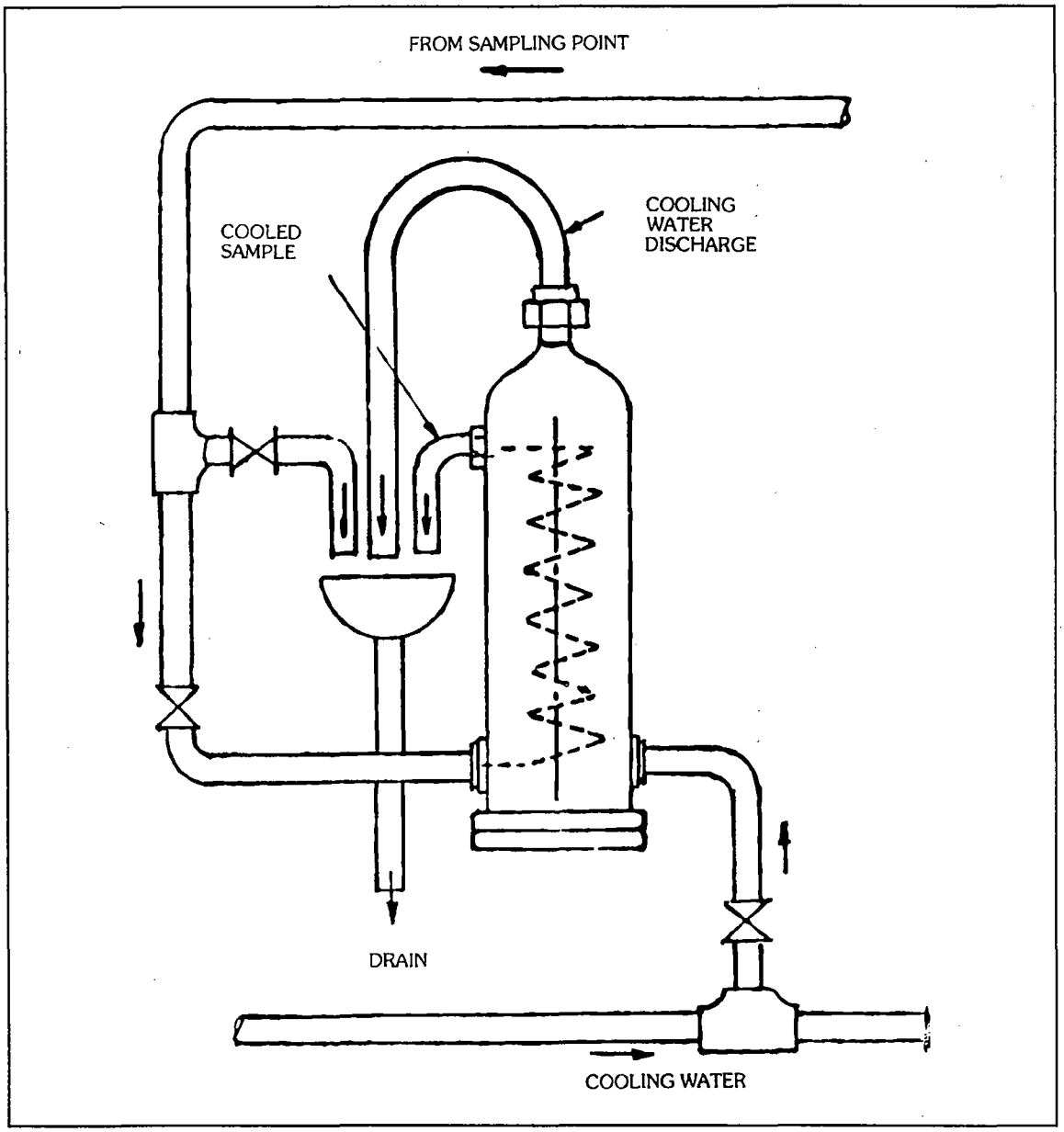

Fig. 14 : Cooling Coils for Boiler Water Sampling

Methods of Analysis :

3.1 **pH :**

A pH comparator with appropriate indicator solution, may be used. Preferably, a pH meter with glass electrodes should be used.

3.2 **Total Dissolved Solids (TDS) :**

(a) Evaporate a known volume (100 ml of boiler water) in a porcelain or platinum dish over a sand bath or hot plate (to avoid spluttering) and dry in an oven at 103^{0}C for one hour. Cool in a desiccator and weigh. Then TDS in ppm shall be

$$TDS = \frac{\text{Weight of residue in gms} \times 10^6}{\text{ml of sample}} \text{ ppm}$$

(b) A fairly accurate result may be obtained, using an electrical conductivity meter.

Both the dissolved and the suspended solids can be determined by method (a) above. For only dissolved solids the sample has to be filtered. For suspended matter only, both the filtered and unfiltered samples have to be evaporated. The difference will give the suspended matter.

3.3 Alkalinity :

Three alkalinities are determined in boiler water analysis viz.

(a) *Phenolphthalein alkalinity*

(b) *Methyl orange alkalinity* and

(c) *Hydroxide alkalinity or Phenolphthalein $BaCl_2$ alkalinity.*

(a) *Phenolphthalein alkalinity (P) :* Take 50 ml of the cooled and filtered sample in a flask and add 2-3 drops of phenolphthalein solution. If no pink colour appears P is zero. If pink colour appears titrate with 0.02 N sulphuric acid till the pink colour just disappears.

Then P in ppm $CaCO_3$ = ml of acid used in titration x 20.

(b) *Methyl orange alkalinity (M) :* Proceed as for (P) but use methyl orange solution instead of phenolphthalein. Titrate using 0.2 N sulphuric acid. The end point is a salmon pink colour. This may be difficult to discern and it may help to keep an untitrated sample containing methyl orange for comparison. Then M in ppm $CaCO_3$= ml of acid used x 20.

(c) *Hydroxide alkalinity (OH alkalinity) :* Cool and filter the sample using activated carbon as filter-aid. To 50 ml of the sample add 10 ml of $BaCl_2$, mix well and allow it to stand for 5 minutes. Add 2-3 drops of phenolphthalein. If a pink colour appears titrate with H_2SO_4 (0.02N) till the colour just disappears.

The OH alkalinity in ppm of $CaCO_3$ = ml of acid used x 20

Alkalinity is expressed in bicarbonate, carbonate and hydroxide forms. Standard practice assumes that titration to P end point determines all hydroxide and one-half of carbonate alkalinity and methyl orange titration measures sum of bicarbonate, carbonate and hydroxide. The Table No. 1 gives the form of alkalinity in water for each of the five different P and M conditions.

Table No. 7

P and M Alkalinity	Hydroxide OH	Carbonate (CO_3)	(Bicarbonate) (HCO_3)
P = O	O	O	M
P = M	M	O	O
P = ½M	O	M	O
P = ½M	O	2P	M-2P
P = ½M	2P-M	2(M-P)	O

3.4 **Chlorides :**

Pipette 50 ml of cooled and filtered sample into a casserole, add 2-3 drops of phenolphthalein and neutralize with 0.02 N sulphuric acid solution. If the solution does not turn pink add a few drops of 0.02 N sodium carbonate solution and neutralize. Add about 6 drops of potassium chromate solution. Then add 0.0171 N silver nitrate solution from a burette while stirring continuously, until a faint orange colour persists.

The burette reading times 20 gives ppm of sodium chloride (NaCl).

To convert from NaCl to Cl multiply the result by 0.6066.

3.5 **Dissolved Oxygen :**

Sample :

To be collected in glass stoppered bottles of 250 ml capacity. The water to be tested should be passed into the bottle through a glass or rubber tube extending to the bottom of the bottle. Where the dissolved oxygen is to be determined on hot water samples, the water should be cooled by passing through a cooling coil before the bottle. Withdraw sampling tube from the bottle before shutting off the water and replace glass stopper immediately in such a manner as to avoid entrapping air bubbles.

Procedure :

Remove stopper from the bottle of boiler water and quickly add one ml of manganous sulphate with a one ml pipette, keeping tip of the pipette below the surface of the water. In the same manner using 2 ml pipette, add 2 ml of alkaline iodide solution. Stopper the bottle and shake thoroughly. Allow the ppt to settle and as soon as it has settled, quickly add 2 ml of 1: 1 H_2SO_4 keeping the tip of the pipette below the surface of the water. Replace the stopper in the bottle and again mix thoroughly until the ppt has completely dissolved. Pipette 100 ml of the water into a 250 ml Erlenmeyer flask and titrate with 0.025 N sodium thiosulphate until the yellow colour almost fades out. Add one ml of starch solution and continue the titration drop by drop until the blue colour just disappears.

Then dissolved oxygen in ppm equals ml of sodium thiosulphate used multiplied by two and by the correction factor.

3.6 **Hardness :**

(Note : Boiler water which shows phenolphthalein alkalinity and soluble phosphate content will always have zero hardness).

3.6.1 Total Hardness :

To 50 ml of filtered sample add 1.0 ml of buffer solution and a small amount of Eriochrome Black T indicator solution. Then titrate with hardness reagent (EDTA). The colour change is from red to blue with an intermediate purple colour. The end point is shown by disappearance of the last purple colouration. Thorough mixing or stirring is necessary after addition of each reagent and during titration.

Calculation :

The number of ml of hardness reagent used times 20, equals the total hardness expressed as ppm of $CaCo_3$.

3.6.2 Calcium Hardness :

Pipette 50 ml of filtered water sample into an Erlemeyer flask and 2 ml of sodium hydroxide solution. Add a few drops of Eriochrome Black T indicator solution and titrate with hardness reagent (EDTA.) The end point is indicated by colour change from salmon pink to blue-violet.

Calculation :

The number of ml of hardness reagent used times 2 equals the calcium hardness expressed as ppm of $CaCO_3$.

3.6.3 Magnesium Hardness :

This may be found by subtracting calcium hardness from total hardness.

3.7 **Soluble Phosphate :**

Colorimetric Method :

Use Klett - sumerson Photoelectric colorimeter with solution cell 80 x 40 x 10 mm and Red Filter No. 66.

A. *Blank Solution :*

Pipette exactly 5 ml of ammonium molybdate solution prepared for phosphate determination into a 50 ml vol. flask, dilute to about 40 ml with distilled water and mix thoroughly.

B. *Standard Solution :*

Prepare a 10 ppm PO_4 standard phosphate solution by taking 10 ml of 50 ppm, PO_4 solution into a vol. flask diluting to about 35 ml with distilled water. Add 5 ml of ammonium molybdate solution and mix thoroughly.

Add 2 ml of amino-naphthol sulphonic acid to each of the above solutions and mix. Fill both the flasks to the 50 ml mark with distilled water, mix the contents thoroughly and allow them to stand for 10 min.

Now take readings with the colorimeter which has been warmed up and set to read zero with distilled water at solution cell depth of 10 mm using red filter for solutions A and B.

(Note : Intensity of colour tends to increase with time. All readings should, therefore, be made between 10 and 25 minutes after the reagents are mixed for colour development).

Correct the standard reading by subtracting the blank reading

(B - A) and determine the conversion factor by dividing 10 by the corrected standard reading $\frac{10}{B-A}$

C. *Sample Reading :*

Cool and filter the sample of boiler water using washed activated carbon. Pipette 10 ml of the filtered sample into a 50 ml vol. flask, dilute to about 35 ml of distilled water and mix thoroughly. Proceed for colour development by adding 5 ml of ammonium molybdate and add 2 ml of amino naphthol sulphonic acid solution. Take the reading in the colorimeter. Correct the sample reading by subtracing the blank reading (C-A).

Calculation :

Phosphate, ppm PO_4 = Comversion factor x corrected sample reading x 5

Note : If the reading is too high (over 500) repeat the analysis on a smaller aliquot. Then,

ppm PO_4 = Conversion factor x corrected sample reading x $\frac{50}{\text{(ml) aliquot}}$

3.8 **Sulphite :**

Take 0.5 ml of HCI into a casserole and pipette 50 ml of sample into it and add 1.0 ml of starch indicator. Titrate drop by drop with standard Potassium iodide-iodate solution until a permanent first blue colour develops.

Calculation :

The amount of sulphite present expressed as parts per million of SO_3 equals burette reading x 10.

3.9 **Silica :**

Colorimetric method :

Use the Klett Summerson photoelectric colorimeter as for phosphate determination.

A. *Blank Solution :*

35 ml distilled water in a 50 ml vol. flask.

B. *Standard silica solution :*

Prepare a 2 ppm SiO_2 solution by taking 10 ml of 10 ppm SiO_2 into a 50 ml. vol. flask and diluting with 35 ml of distilled water. Mix thoroughly to each of the above add 1.0 ml of ammonium molybdate (prepared for silica determination), mix and set aside for 5 min. Then add 4 ml of citric acid and mix and then 2 ml of amino naphthol sulphonic acid solution and mix. Fill the flasks to 50 ml mark with distilled water and allow them to stand for 15 min. Then take readings in the colorimeter set to zero with distilled water at solution cell depth of 10 mm using the red filter. Correct the standard reading by subtracing the blank reading and determine the Correction Factor by dividing 2 by the corrected standard reading.

C. *Sample Reading :*

Pipette 10 ml of cooled and filtered sample (filtering should be done with washed active carbon), in a 50 ml vol. flask and dilute with about 35 ml distilled water and mix. Then add and mix ammonium molybdate, citric acid and amino naphthol sulphonic acid as above for colour development and allow it to stand for 15 min. Take the reading on the colorimeter, correct the sample reading by subtracing the blank reading. Then

$$SiO_2 \text{ in ppm} = \text{Conversion factor} \times \text{corrected sample reading} \times \frac{50}{\text{aliquot (ml)}}$$

(Note : Silica determination is made to determine the type and amount of treatment necessary to prevent scaling).

3.10 **Oil (Chloroform extractable matter) :**

Collect the sample in an oil free, tared glass stoppered bottle, weigh the bottle with the sample and transfer the contents into a separating funnel. Add 50 ml of Chloroform ($CHCl_3$, redistilled, mol. wt 119.39) and shake the funnel. Add another 50 ml of chloroform to sample bottle, shake and pour into the separating funnel.

Draw the extract into a tared beaker or flask and evaporate. If the extract is not clear, filter before evaporating and wash filter with flask chloroform. Dry the beaker to constant weight at 100°C.

Calculation :

The weight of oil times one million divided by the weight of the sample gives the oil in ppm.

3.11 **Sugar :**

Sugar may be entrained into the condensate which may be used for boiler feed. It may then cause foaming and priming with consequent danger to equipment and get decomposed into corrosive acidic products. If the quantity entrained is large the boiler water will turn reddish brown and the steam will give out a characteristic odour. It is, therefore, essential to check individual condensates themselves for traces of sugar if any. The feed water should also be tested every half an hour.

Test :

Ensure that the sample container and all glassware used are free from any trace of sugar. Cool a portion of the sample to room temperature. Rinse the test tube two or three times with a portion of the sample and fill to a depth of about 40 mm with the sample.

Add 5 drops of alpha-naphthol solution (preparation given under 4.9.1 below for "Sugar") to the test-tube and mix thoroughly. Hold the test-tube in an inclined position with the tip of the burette containing concentrated sulphuric acid (chemically pure) touching the side of the test-tube. Allow the acid to run into the tube so that it runs to the bottom of the tube forming a definite layer. Give the test-tube held vertically between hands a rolling motion being careful not to mix the layers. If a lilac or purple ring appears at the junction of the layers during the addition of the sulphuric acid of immediately thereafter, sugar is indicated. If no ring appears within 15 seconds the test can be reported as negative.

4. Preparation of reagents required for boiler water analysis :

4.1 For Alkalinity :

4.1.1 *Barium chloride solution (10.0%)*

Transfer 100 g of barium chloride ($BaCl_2.2\ H_2O$) to 1000 ml volumetric flask and half filled with distilled water. Shake until solution is complete, then make to mark with distilled water.

4.1.2 *Methyl orange solution :*

Dissolve 0.20 g of methyl organge indicator in distilled water on a 200 ml vol. flask and complete to volume with distilled water.

4.1.3 *Phenolphthalein solution :*

Weigh 1.0 g of phenolphthalein powder and transfer to 200 ml volumetric flask. Add 100 ml of isopropyl alcohol and dissolve. This solution will be slightly acidic so add cautiously, drop by drop 0.1 N NaOH until faint pink colour appears, then add one drop of 0.1 N H_2SO_4. Complete to volume with distilled water.

4.1.4 *Sulphuric acid (0.02 N) :*

Pipette 20 ml of normal H_2SO_4 into a 1000 ml volumetric flask containing 500 ml distilled water. Make to mark with distilled water.

4.2 **For Chloride :**

4.2.1 Phenolphthalein solution (as given under para 4.1.3 above):

4.2.2 Potassium chromate solution :

Weigh 5.0 gm of potassium chromate and dissolve in approximately 75 ml of distilled water in 250 ml beaker. Add silver nitrate solution 0.05 N until a permanent red precipitate appears. Cover the beaker and let in stand for approximately, 12 hrs. Filter into a 100 ml volumetric flask and complete to volume with distilled water.

4.2.3 **Silver nitrate solution (0.05 N) :**

(Used in the preparation of potassium chromate)

Dry about 9.0 g of $AgNO_3$ on a watch glass at 100°C for 15 minutes. Transfer to desiccator and allow to cool for 15 min.

Weigh 8.5 g on counter balanced watch glass and transfer to a 1000 ml volumetric flask. Add about 500 ml of distilled water and mix. Store in a glass stoppered amber coloured bottle.

If the solution is carefully prepared from absolutely dry, crystals and chloride free distilled water and kept in a tightly stoppered bottle it may be used without standardisation. However, the method of standardisation is given below :

Standardization :

Pipette 25 ml of 0.05 N sodium chloride solution into a 200 ml procelain casserole. Add approx. 75 ml of distilled water and 1 ml of potassium chromate solution. Titrate with the silver nitrate while stirring constantly until a faint but permanent reddish colouration is noticed. The titration should require 25.0 ml of 0.05 N silver nitrate. Adjust to normality or apply proper factor.

4.2.4 *Silver Nitrate solution (0.0171 N) :*

(For chloride determination)

Dry about 3.5 g of silver nitrate ($AgNO_3$) on a watch glass at 100°C for 15 minutes. Transfer to a desiccator and allow it to cool for 15 minutes. Weigh 2.905 g of the above dried material on a counter balanced watch glass and transfer to a 1000 ml volumetric flask. Add about 500 ml of distilled water and dissolve the crystals. Complete the volume and mix. Store in a glass stoppered amber coloured bottle. Shake well before use.

Standardization :

Dry 2 g of sodium chloride crystals in an oven at 100°C for 30 minutes. Cool in a desiccator. Weigh 0.9996 g of NaCl and transfer to a 1000 ml volumetric flask. Fill about half with distilled water and mix until dissolved. Make to mark with distilled water and mix. Pippette 25 ml of sodium chloride solution into a 200 ml porcelain dish. Add approx 75 ml of distilled water and 1.0 ml of above potassium chromate solution. Titrate with the silver nitrate while constantly stirring until a faint reddish colouration is notices. The titration should require 25 ml of 0.071 N silver nitrate. Adjust to normality or find a factor.

4.2.5 *Sodium carbonate solution 0.02 N :*

Weigh 1.06 of anhydrous sodium carbonate on an analytical balance and transfer to a 1000 ml volumetric flask. Fill about half with distilled water and dissolve. Complete to volume with distilled water and mix.

4.2.6 *Sulphuric acid solution (0.02 N)* as given under 4.1.4.

4.3 **For Dissolved Oxygen :**

4.3.1 *Alkaline iodide solution :*

Transfer 90 g of sodium hydroxide and 25 g of potassium iodide to a 250 ml volumetric flask, add distilled water and dissolve the crystals. Complete to volume with distilled water and mix.

4.3.2 *Manganous sulphate soultion :*

Weigh 48 g of manganous sulphate $MnSO_4H_2O$ into a beaker and add 100 ml of freshly boiled and cooled distilled water. Mix until dissolved. Store in an amber coloured bottle.

4.3.3 *Sodium thiosulphate solution (0.025 N) :*

Prepare from 0.1 Stock solution (see below). Pipette 250 ml of the stock solution to a 1000 ml volumetric flask and make to volume with distilled water.

0.1 N stock solution :

Weight 24.82 of sodium thiosulphate ($Na_2S_2O_35\ H_2O$) and transfer to a 1000 ml volumetric flask. Add about 500 ml of distilled water and mix well until the crystals are dissolved. Complete to volume with distilled water and mix.

Standardization :

Pipette 25.0 ml 0.1 N potassium dichromate solution into a 250 ml Erlenmeyer flask, add about 25 ml of distilled water, 2 g of potassium iodide crystals and 7 ml of hydrochloric acid. Titrate with 0.1 N sodium thiosulphate solution until the yellow colour fades out. Add 1.0 ml of starch indicator and continue to titrate drop by drop until blue colour changes to sea green. This titration

should require 25.0 ml of 0.1 N sodium thiosulphate solution. Apply a factor for adjustment to normality. As the thiosulphate solution breaks down gradually losing some of the sulphur, a new factor must be determined by titrating against 0.1 N potassium dichromate solution periodically.

4.3.4 *Potassium dichromate solution : 0.1 N :*

Weigh 4.9035 g of potassium dichromate $K_2Cr_2O_7$ crystals on an analytical balance and transfer to a 1000 ml volumetric flask containing 500 ml of freshly boiled and cooled distilled water. Complete to volume with the above water and mix. Store in a stoppered amber coloured bottle. Shake well each time before use.

4.3.5 *Starch indicator solution (1.0%) :*

Dissolve 1 g of water soluble starch in 50 - 75 ml of saturated salt solution warming a little if necessary. Transfer to a 100 ml volumetric flask and make to mark with saturated salt solution. To make a saturated salt solution add 140 ml of distilled water to 50 g sodium chloride (NaCl) in a 250 ml beaker. Heat to boiling, cool and decent the clear liquid.

4.3.6 *Sulphuric acid 1:1:*

Place a 1000 ml beaker containing 500 ml of distilled water in a bath of cold running water. From a graduated cylinder, carefully and slowly, pour 500 ml of sulphuric acid down the inside of the beaker while constantly stirring the mixture. Cool and wash into 1000 ml volumetric flask. Complete to volume with distilled water.

4.4. **For Hardness :**

4.4.1 *Hardness buffer solution :*

Solution No. 1:

Dissolve 40.0 g of sodium tetra borate ($Na_2B_4O_7$. 10 H_2O) in approx. 800 ml of distilled water.

Solution No. 2 :

Dissolve 10.0 g of sodium hydroxide and 5.0 g of sodium sulphide (Na_2S) in 100 ml of distilled water.

Cool and mix the two solutions in 1000 ml vol. flask and make to mark with distilled water. Store in amber coloured bottle well stoppered.

4.4.2 *Hardness reagent :*

Dissolve 4.0 g of disodium ethylene diamine tetra acetate ($Na_2C_{10}H_{14}O_8N_2.2$ H_2O) in about 800 ml of distilled water. Add 0.86 g of sodium hydroxide and make upto 100 ml in a volumetric flask with distilled water. Store in an amber coloured bottle.

Standardization :

Pipette 25.0 ml of calcium chloride solution into a 250 ml in an Erlenmeyer flask. Add 25 ml of distilled water. Add 1.0 ml of hardness buffer solution, mix add 4 drops of Eriochrome Black T indicator solution and titrate with hardness reagent. The colour change is from red to blue with an intermediate purple colour. The end point is obtained when the last purple colouration just disappeares. The titration should require 25.0 ml of hardness reagent. Adjust to exact normality as necessary.

4.4.3 *Eriochrome black T indicator :*

To 30 ml of distilled water add 1 ml of N sodium carbonate solution and 1.0 g of Erichrome Black T and mix. Make to 100 ml with isopropyl alcohol and mix. Store in an amber coloured bottle.

4.4.4 *Sodium hydroxide solution (Approx. 1 N) :*

Counter balance a 100 ml beaker on an analytical balance and weigh rapidly 42.5 g of sodium hydroxide pellets. Transfer to a 100 ml volumetric flask and fill about half with distilled water. Mix until dissolved. Cool to room temperature and make up the volume with distilled water. Mix thoroughly and store in rubber stoppered or polythene bottle.

4.5 **For Phosphate :**

4.5.1 Ammonium molybdate solution (For determining 'Phosphate')

Dissolve 30 g of ammonium molybdate $(NH_4)_6MO_7O_{24}4H_2O$ in 350 ml of distilled water. Add 600 ml of 10 N, sulphuric acid slowly while stirring. Cool make upto 1 litre with distilled water and store in a polythene bottle.

4.5.2 Amino naphthol sulphonic acid solution :

Dissolve 1.5 g of 1-amino-2 naphthol-4 sulphonic acid $NH_2C_{10}H_6SO_3H.\ H_2O$ and 7.5 g of sodium sulphite $Na_2SO_3.\ 7H_2O$ of 3.8 g of anhydrous Na_2SO_3 in 100 ml distilled water. The mixture may be warmed to hasten solution. Add 79.7 g of sodium bisulphite ($NaHSO_3$) dissolved in 700 ml of distilled water. The mixture may be warmed to hasten solution. Add 79.7 g of sodium bisulphite ($NaHSO_3$) dissolved in 700 ml of distilled water. Make to 1000 ml with distilled water. Store in and amber coloured bottle. This solution is unstable and should be freshly prepared every four months.

4.5.3 Standard phosphate solution 50 ppm PO_4 :

First prepare a 1000 ppm PO_4 stock solution by dissolving 1.433 gm oven dried potassium phosphate monobasic KH_2PO_4 in a 1000 ml. vol. flask with distilled water. Make to mark and mix and store in polythylene bottle. Standard phosphate solution 50 ppm PO_4 can then by prepared by taking 25 ml of the above stock solution and diluting it to 500 ml with distilled water.

4.6 **For Sulphite :**

4.6.1 Potassium iodide-iodate solution (0.1025N) :

Weigh 0.45 g of potassium iodate KIO_3 on an analytical balance. Transfer to a 100 ml volumetric flask and add about 100 ml of distilled water. Mix until dissolved. Add 4.35 g potassium iodide (KI) and 0.31 g of sodium bicarbonate ($NaHCO_3$). Mix until dissolved. Complete to volume with distilled water and mix.

Standardization :

Pipette 0.5 ml of conc. hydrochloric acid into a 100 ml. porcelain dish. Pipette 25 ml of 0.0125N sodium thiosulphate solution into the dish. Add 1 ml of starch indicator. Titrate with 0.0125 N potassium iodide-iodate solution until a permanent blue colour develop.

The titration should require 25 ml of 0.0125 N potassium iodide-iodate solutions. Adjust to normality.

4.6.2 Sodium thiosulphate (0.0125 N) solution :

Prepare from 0.1 N stock solution (as under Dissolved Oxygen) Pipette 125 ml of 0.1 N stock solution to 1000 ml volumetric flask and make to volume with distilled water.

4.7 **For Silica :**

4.7.1 Ammonium molybdate solution : (For determination of 'Silica') dissolve 100 g of ammonium molybdate in 700 ml of distilled water. Add 250 ml of 10N sulphuric acid solution slowly while stirring and cool. Add 1 drop of conc. nitric acid, make upto 1 litre with distilled water and store in a polyethylene bottle.

4.7.2 Citric acid solution 10% :

Dissolve 100 g of citric acid ($H_3C_6H_5O_7 . H_2O$) and dilute to 1000 ml with distilled water. Add 0.4 g benzoic acid and dissolve. Store in a polyethylene bottle.

4.7.3 Amino naphthol sulphonic acid : As under phosphate : (4.5.2)

4.7.4 Standard silica solution 10 ppm SiO_2 :

Fuse 0.500 g pure powdered anhydrous silica with 5 g sodium carbonate in a platinum crucible. Heat at slightly above fusion temperature for 15 minutes, cool and dissolve the melt in warm distilled water. Cool transfer to a 1000 ml volumetric flask, dilute to mark and mix thoroughly. Store in a polyethylene bottle. (This is the standard stock solution, 500 ppm SiO_2). To prepare 10 ppm SiO_2 solution dilute 10 ml of the above to 500 ml with distilled water in a volumetric flask and store in a polyethylene bottle.

4.8 **For Oil :**

4.8.1 Chloroform, redistilled, molecular weight 119.39.

4.9 **For Sugar :**

4.9.1 Alpha - naphthol :

Transfer 5.0 g of alpha-naphthol ($C_{10}H_7OH$) purified for sugar test to a 100 ml vol. flask, add about 75 ml of isopropyl alcohol or ethyl alcohol and dissolve. Complete to volume with the alcohol. Mix well and store in an amber coloured bottle.

(Note : A fresh soultion should be prepared every month).

Its senstivity should be checked against a sugar solution containing one part of sugar in 1,00,000 parts of distilled water.

5.0 **Water Quality Easytest Kits :**

Regular analysis of water is essential for maintenance of boilers and demineralisers. Conventional procedures for water analysis require elaborate laboratory set up and qualified personnel. Few Companies e.g. M/s Ion Exchange (India) etc. offer Easytest Kits for analysing feed & boiler water characteristics quickly and with reasonable degree of accuracy. The test kit replaces analytical procedures such as titrimetric, colorimetric/ spectophotometric by simple drop tests and standard colour comparison methods. These can be carried out by the operators themselves, making monitoring and preventive action very quick and convenient.

CHAPTER – VII

MEASUREMENT OF HYDROGEN ION CONCENTRATION (pH)

CHAPTER – VII

MEASUREMENT OF HYDROGEN ION CONCENTRATION (pH)

In the technology of cane juice clarification, acidity or alkalinity of the juice is of considerable significance. If the acidity is too high, the sucrose in the juice will be inverted resulting in the loss of sugar. If the alkalinity becomes too high the glucose in the juice would decompose resulting in the formation of coloured salts of organic acids. The acidity or alkalinity is therefore required to be measured in order to control the involved reactions. The usual method of measuring would be to titrate a known volume of the test solution with an alkali or acid of known normality. But it is seen that in regard to the inversion of sucrose, different acids cause different amounts of inversion even though their concentrations are the same for example normal H_2SO_4 and normal H_3PO_4 require the same amount of alkali for neutralisation indicating that their potential acidity is the same, but their effect on inversion is quite different. It has been found that dissociation of H^+ ions in aqueous solutions is different for different acids and it is the dissociated H^+ ions that cause inversion. Instead of measuring the acidity it would therefore be appropriate to measure the extent of dissociation of H^+ ions. We may say that it is not the quantity but the intensity of acidity, that needs to be measured.

Side by side, determination pH of various condensates, feed water and boiler water etc. should be made an essential part of the analytical work being carried out on hourly basis in the laboratory. With the advent of the high pressure boilers, there is much more need for such a analysis.

1. DEFINITION OF pH.

The extent of dissociation of H^+ ions (or OH^- ions) is denoted by the term "pH" as will be clear from the definition of 'pH' given below:

It is known that the product of $[H^+]$ and $[OH^-]$ ions concentration is always a constant at constant temperature viz.

$$[H^+] \times [OH^-] = \frac{1}{100000000000000} = 1 \times 10^{-14}$$

at 22°C

In order to avoid the expression of hydrogen ion concentration in unwieldy fractions Sorenson suggested the use of the logarithm of the H-ion concentration.

The term pH may be defined as the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration i.e.,

$$pH = \log_{10} \frac{1}{[H+]}$$

In pure water as well as in a neutral solution the concentration of $[H^+]$ and $[OH^-]$ being equal, the concentration of hydrogen ions is equal to 10^{-7}. The pH value of such a solution will thus be

$$pH = -\log 10^{-7} = 7.0$$

The solutions with pH values below 7.0 are acidic and solutions with pH values above 7.0 are alkaline. The entire pH range is thus from 0 to 14. The limit of acidity being represented by pH = 0 and the limit of alkalinity being represented by pH = 14.

Successful sugar manufacture, both in respect of quality and recovery, depends on proper control of pH of the technical sugar solutions during the various stages of processing. In the determination of pH it is, therefore, of great importance that the method used is reliable and sufficiently accurate for the control. In view of this, all the necessary precautions should be strictly adhered to, so that the result obtained is within the limits of accuracy of the method employed.

2. METHODS OF pH DETERMINATION :

The determination of pH of technical sugar solutions may be made either by the colorimetric method or by the electrometric method. The former method gives only an approximate indication of the pH value but is simple, quick and good enough for routine process control purposes.

2.1 The colorimetric method :

This employs the use of

(a) Comparators and (b) Test papers :

Certain dyes or indicators develop different colour tints when acted upon by solutions of different pH value. This property of the indicators is utilized in the above mentioned colorimetric methods. The various indicator solutions, used in comparators or for the preparation of test papers employed for process control purposes in a sugar factory are given in the table no. 8 (on the next page). Their pH range, colour change and stage of the process where applied are also stated.

They are prepared by taking the quantities of the solid indicator powder and standard alkali indicated in the table and grinding them together in an agate mortar with agate pestle and transferring to a 250 ml flask and making up to mark with double distilled water.

2.1.1 *Use of Comparators :*

Two types comparators viz (a) The Taylor Comparator and (b) and Hellige comparator are commonly in use in India. The method of using them is described below :

(a) The Taylor Slide Comparator :

It consists of a sliding tube rack, carrying alternate tubes of distilled water and colour standards and a metallic or plastic frame or cover with suitable apparatus for seeing and comparing the colours. The instrument is provided with a number of such slides, each slide containing a complete set of standard buffer solutions and buffer mixtures (see para 3 ahead) for a given indicator in steps of 0.2 pH. Immediately in front of the sliding racks are sockets for three removable tubes for the solution to be tested, spaced the same distance as the tubes in the rack. Ordinary day light or any of the artificial day light lamps serves as a light source.

TABLE NO. 8

	Indicator	pH range	Colour Change	Wt. of Indicator in gms	ml of 0.01 M NaOH ±±	Application
(i)	**Bromocresol green** (B.C.G.)	3.8-5.4	Yellow-Blue	0.1	14.9	Pre-sulphitation
(ii)	**Methyl red** (M.R.)	4.2-6.3	Red-yellow	0.05	18.5	Syrup Sulphitation, mixed juice, mill juices.
(iii)	**Chlorophenol red** (C.P.R.)	4.8-6.4	Yellow-red	0.1	23.5	Syrup sulphitation, sugars
(iv)	**Bromothymol Blue** (B.T.B.)	6.0-7.6	Yellow-blue	0.1	16.0	Juice sulphitation, clear juice, syrup.
(v)	**Phenol red** (P.R.)	6.8-8.4	Yellow-red	0.1	28.5	Boiler feed water, condensates
(vi)	**Cresol red**	7.2-8.8	Yellow-red	0.1	26.2	Second carbo-nation and final sulphitation of juice.
(vii)	**Thymol blue** (T.B.O.)	8.0-9.6	Yellow-blue	0.1	21.5	Preliming, boiler feed water
(viii)	**Phenolphthalein***	8.0-9.6	Chlourless Pink	See text below		Very highly alkaline juices
(ix)	**Thymolphthalein****	10.2-11.7	Colourless Pink			

* *The solution of phenolphthalein isprepared by dissolving 0.25g of the indicator powder in 5 ml of 97.5% alcohol in 250 ml flask. After dilution with distilled water, sufficient 0.1 N sodium hydroxide is added to produce faint rose tint and made upto 250 ml.*

** *For thymolphthalein. 0.125g of the indicator powder is dissolved in 200 ml of 97.5 ± alcohol in a 250 ml flask. Several drops of 0.1 N sodium hydroxide are added and the volume made upto 250 ml with distilled water. The solution should have a light yellow-green tint.*

±± *NaOH is added to effect a sharp colour change over a narrow range of pH.*

For determining the pH of the solution, the slide corresponding to the indicator used, is placed on the main frame carrying the assembly. The three tubes are filled with 5 ml of the solution under test and 0.5 ml of the indicator solution mentioned in the table above, is added to the central tube. The indicator selected should be such that the pH of the solution to be tested lies approximately in the middle of the useful range of the indicator. The contents of the central tube are thoroughly mixed (Thumb should not be used to close the tube for shaking as the acid of the perspiration interferes with the result). The colour standard slide in moved in front of the test samples until a colour match is obtained. The pH is then read directly from the value on the slide.

(b) The Hellige Disc Comparator :

It is similar in principle to the Taylor comparator. In this comparator the place of the standard solutions in tubes is taken by transparent coloured glasses. These tinted glasses are arranged on a circular disc and are in steps of 0.2 pH. As with the slide comparator, each disc contains a complete set of standards for a given indicator and these discs are inter-changeable on the instrument. The disc is so mounted on the block that standard glass can be moved to position just in front of one of the two tubes placed in position in the comparator and containing the solution under test without the indicator. Two tubes of exactly similar dimensions are provided with the instrument. These are each filled with 10 ml of the solution under test. To one of the tubes containing the test solution is added 0.5 ml of the indicator solution and the contents thoroughly mixed. The two tubes are placed in position so that the test tubes without the indicator solution is behind the standard tinted glass. The determination is made by observation through the block with the tubes in place while the disc holding the standard glasses is rotated until a colour standard matches the colour of the solution containing the indicator and then the pH is read off on the disc.

2.1.2 *Use of Test papers :*

Filter paper sheets of the type similar to Whatman No. 1 are cut into strips about 8 cm wide. They are washed in hot double distilled water and dried. The paper strips are then dipped in the required indicator solution, the preparation of which has been described in the previous para (2.1). Care is taken to see that the paper absorbs the solution properly, the excess solution on the paper is wiped out by a lean glass

rod; the papers are then kept suspended for drying in shade in an atmosphare free from acid or alkaline fumes. After drying, they are cut into suitable size (0.5 x 8 cm) and kept in airtight bottles.

For not so precise an indication, the required indicator solution for test papers may also be prepared by dissolving 0.2 g of indicator (fresh) in 50 ml of rectified spirit and making upto 350 ml with double distilled water.

The Test papers to indicated the required alkalinity or pH in the carbonation process are prepared as follows:

(i) Dupont paper (for the control of first carbonation; alkalinity 400 mg CaO/litre)*

Dissolve, 1.8008 gm of oxalic acid in water and make up to 1 litre with distilled water. Dissolve 2 gm of phenophthalein in 850 ml of rectified spirit and add a few drops of dilute NaOH until it is very slightly pink and make up to one litre with distilled water. Mix the two solutions and filter the mixture. Strips of neutral filter paper are soaked in the mixture and dried in acid free atmosphere.

(ii) Dupont paper (for second carbonation; alkalinity 100 mg CaO/ litre) :

Dissolve 0.45 gm of oxalic acid in one litre solution of distilled water. Add 1 gm of phenolphthalein in850 ml of neutral alcohol and make up to 1 litre with distilled water. Mix the two and filter the mixture, dip neutral filter sheets, dry and cut strips.

(iii) Thymol blue paper (for second carbonation; pH 8.3-10.0) :

0.5714 gm of thymol blue dye is ground in rectified spirit for 45 minutes. The alcohol required to dissolve the solution is about 150 ml and the volume is made up with distilled water to 1000 ml, dip neutral filter strips and dry.

(iv) Phenolphthalein paper (for second carbonation; 100 mg CaO/litre) :

One gm of P.P. dye, dissolved in rectified spirit and made up to 1 litre with rectified spirit or alcohol.

(v) Thymol blue (for thin juice sulphitation)

Dissolve 0.2857 mg of T.B. powder in 70 ml of neutral alcohol and make up to 500 ml with double distilled water and filter.

(vi) Bromo thymol blue (for sulphitation process)

0.2857 gm of B.T.B. powder is dissolved in 50 ml of rectified spirit and the solution is neutralised with weak NaOH solution and then made up to 500 ml. After soaking and drying in acid free

atmosphere the filter paper is cut into strips and kept in glass stoppered bottle.

* *Alkalinity is determined by titrating 10 ml of filtered juice with N/28H_2SO_4 using phenolphthalein as the indicator. 1.0 ml of the acid is equivalent to 100 mg of CaO per litre or 4 ml of acid used indicates an alkalinity of 400 mg per litre of CaO.*

2.2 **Electrometric method :**

This method is very accurate. It depends on the measurement of the potential developed by an electrode when placed in the solution whose pH is to be determined. Various types of electrodes are used such as, the hydrogen electrode, the quin hydrone electrode, the antimony electrode and the glass electrode. Of these the glass electrode is the most accurate, particularly in the case of sugar factory liquors and least subject to errors. Sturdy assemblies suitable for laboratory as well as plant work are easily available and pH can be determined electrometrically with much greater accuracy and speed than colorimentrically and this method should therefore be used as far as possible.

The use of Glass Electrode :

The glass electrode is undoubtedly the most reliable for measurement and control of pH in industrial processing. The glass electrodes of earlier times were very thin and highly fragile. Development of special glass compositions as well as the design of sensitive pH meters based on electrometric valves has made it possible to have stout glass electrodes as can be recommended for use in the industry. A number of good pH meters are available in the market and can be purchased according to the individual's requirement. The selection of a pH meter should be done after ensuring that the circuit design, nature of the components used as well as the actual fabrication are such as to ensure proper performance with robust glass electrodes. The instrument should be kept preferably in an enclosure having low level of humidity. It would also be necessary to have a steady source of A.C. supply, the observed type and extent of fluctuations in voltage and frequency (phase and no. of cycles) should be communicated to the maker to ensure that their instrument is designed for such a supply. Alternatively battery-worked pH meters can be used. While working with a pH meter, spillage of solutions should be avoided as it may enhance surface conductance and the resulting current leakage may upset the working of the pH meter. The glass electrode should be checked up every day during use for its good performance with two standard buffers in the pH range of the test solution. Special glass electrodes are now available for accurate determination of pH even at the highest alkalinity.

The following precautions must be taken :

(a) Glass electrode should be kept immersed in distilled water for at least 24 hrs before use. Even when not in use, keep it immersed in distilled water.

(b) A crystal of KCl should be left in the reference solution chamber if the reference electrode is saturated colomel electrode.

(c) All test samples should be cooled to room temperature.

(d) Temperature compensation to be made as specified in the instrument.

(e) Samples should be tested without dilution if possible. For raw sugar dissolve 2 parts sugar in one part or less of water; for molasses use 1:1 dilution. For white sugar 50 brix solution to be used at 20°C.

(f) The electrode should be kept immersed in test solution for at least 5 min before taking the reading.

3. BUFFER ACTION AND STANDARD BUFFER SOLUTIONS AND BUFFER MIXTURES :

A buffer solution is one which represses the ionisation of acids and bases and maintains its pH value over a wide range, even when diluted with water or when any acid or alkali is added.

Solutions encountered in cane sugar factory control show buffer action to a high degree. However solutions of pure granulated sugar exhibit no buffer action at all.

Buffer solutions are of the greatest importance in pH work, such as for periodical checking of the accuracy of the different methods used. Every care should, therefore, be taken in their preparation.

3.1 Preparation of Standard Buffer Solutions * :

3.1.1 *Potassium tetra oxalate buffer* :

12.71 g of potassium tetraoxalate dihydrate, $KH_3 (C_2O_4)_2\ 2\ H_2O$, are dissolved and made upto one litre in high quality distilled water to give a 0.05 M solution of pH 1.68 at 20°C.

3.1.2 *Phthalate buffer* :

10.21 g of potassium hydrogen phthalate $KHC_8H_4O_4$, are dissolved in distilled water and made upto one litre to give a 0.05 M solution of pH 4.00 at 20°C and 4.01 at 28°C.

3.1.3 *Phosphate buffer* :

3.40 g of potassium dihydrogen orthophosphate, KH_2PO_4 and 3.55 g of disodium hydrogen orthophosphate Na_2HPO_4 are dissolved and made upto one litre in high quality distilled water to give 0.025 M solution of pH 6.88 at 20°C and 6.85 at 28°C. On account of its hygroscopicity the disodium hydrogen orthophosphate should be dried at 110-130°C for about 2 hours before weighing.

3.1.4 *Borax buffer* :

3.81 g of disodium tetraborate, $Na_2B_4O_7.\ 10\ H_2O$, is dissolved and made upto one litre in CO_2 free water to give a 0.01 M solution of pH 9.22 at 20°C and 9.15 at 28°C. The solution must be protected at all times from atmospheric carbondioxide.

3.1.5 *Calcium hydroxide buffer* :

A saturated solution of calcium hydroxide is made in CO_2 free water at 25°C to give about 0.023 M solution of pH 12.63 at 20°C. The presence of excess of $Ca(OH)_2$ does not materially effect the pH value at temperatures upto 80°C.

* *(From Cane Sugar Handbook" by C.P. Chen, 11th Edition.)*

As pH changes with temperature, the pH values of the above mentioned standard buffer solutions at different temperature (0 to 95°C) are given in the Table No. 9.

TABLE NO. 9

Temp. °C	0.05 M K tetra oxalate	0.05 M KH phthalate	0.025 M KH_2PO_4 0.025 M Na_2HPO_4	0.01 M Borex	$Ca(OH)^2$ saturated at 25°C
0	1.67	4.01	6.98	9.46	13.43
5	1.67	4.01	6.95	9.39	13.21
10	1.67	4.00	6.92	9.33	13.00
15	1.67	4.00	6.90	9.27	12.81
20	1.68	4.00	6.88	9.22	12.63
25	1.68	4.01	6.86	9.18	12.45
30	1.69	4.01	6.85	9.14	12.43
35	1.69	4.02	6.84	9.10	12.14
40	1.70	4.03	6.84	9.07	11.99
45	1.70	4.04	6.83	9.04	11.84
50	1.71	4.06	6.83	9.01	11.70
55	1.72	4.07	6.84	8.99	11.58
60	1.72	40.9	6.84	8.96	11.45
70	1.74	4.12	6.85	8.93	–
80	1.77	4.16	6.86	8.89	–
90	1.80	4.20	6.88	8.85	–
95	1.81	4.23	6.89	8.83	–

* *From "Cane Sugar Handbook" by C.P. Chen, 11th Edn.*

3.2 Standard buffer mixtures to indicate pH values in steps of 0.2 pH with different indicators :

These are required to serve as standard solutions for comparison in comparators. They are prepared by first preparing the stock buffer solutions and then mixing them as shown in the table below :

Stock Buffer solutions :

3.2.1 *Potasium hydrogen orthophthalate* ($KHC_8H_4O_4$)

Dissolve 4.836 g of the salt in one litre of double distilled water to obtain 0.2 M solution.

3.2.2 *Potassium dihydrogenphosphate* (KH_2PO_4)

Dissolve 27.232 g of the salt in distilled water and make upto one litre to obtain 0.2 M solution.

3.2.3 *Boric acid – Potassium chloride mixture* (H_3BO_3+KCl)

Dissolve 14.912 g of KCl and 12.405 of boric acid in water and make upto one litre to obtain 0.2 M solution.

3.2.4 *Glycocoll – Sodium chloride mixture*

Dissolve 7.505 g of glycocoll and 5.85 g of sodium chloride in distilled water and make up to one litre.

3.2.5 *Stock 0.2 M NaOH solution*

Dissolve 25 g of NaOH in 25 ml distilled water. Put the solution in a Jena or Pyrex test tube and keep it closed by a cork wrapped in filter paper. Allow it to stand for a week. The sodium carbonate which is an impurity being insoluble in conc. NaOH solution settled down. Decant the clear supernatant liquid into a conical flask and dilute it with CO_2 free distilled water sufficiently to get nearly one normal solution. Find out the exact normality by titrating against standard HCl using methyl orange as indicator. Dilute the above solution ten times and five times to get one tenth molar and one fifth molar solution. In the case of sodium hydroxide, normality and molarity are identical.

Mix 50 ml of the above (0.2 M) buffer solutions with the quantities of 0.2 M NaOH as given in table no. 10 below and make up the volume to 200 ml, in order to obtain the specified pH in steps of 0.2 pH at 20°C. For example, to obtain a buffer mixture of pH 6.4, mix thoroughly, 50 ml of 0.2 M KH_2PO_4 with 12.60 ml of 0.2 M NaOH and make up the volume to 200 ml.

TABLE NO. 10

50 ml 0.2 M Opthalate		50 ml of 0.2 M KH_2PO_4		50 ml of 0.2 M H_3BO_3		ml of glycocoll NaOH + NaCl	ml of 0.1 M NaOH	pH
ml of 0.2 M NaOH	pH	ml of 0.2 M NaOH	pH	ml of 0.2 M NaOH	pH			
0.40	4.0	3.72	5.8	2.61	7.8	140	60	9.66
3.70	4.2	5.70	6.0	3.97	8.0	120	80	10.09
7.50	4.4	6.70	6.0	5.90	8.2	110	90	10.42
12.15	4.6	12.60	6.4	8.50	8.4	102	98	11.01
17.70	4.8	17.80	6.6	12.00	8.6	100	100	11.25
23.85	5.0	23.65	6.8	16.30	8.8	98	102	11.51
29.95	5.2	29.63	7.0	21.30	9.0	90	110	12.04
35.45	5.4	35.00	7.2	26.70	9.2			
39.85	5.6	39.50	7.4	32.00	9.4			
43.00	5.8	42.80	7.6	36.85	9.6			
45.45	6.0	45.20	7.8	40.80	9.8			
47.00	6.2	46.80	8.0	43.90	10.0			

These buffer mixture should be stored in pyrex or jena glass bottles.

CHAPTER – VIII

CONTROL PARAMETERS

CHAPTER – VIII

CONTROL PARAMETERS

Note :

(i) The weights of all the quantities entering into accounting control should be determined very accurately.

(ii) All the averages should be weighted or true averages (except for pH)

(iii) Suitable indicating and recording control instruments duly checked and calibrated should be installed at the different stations of the factory to ensure dependable control data.

1. Milling Control

The following figures should form the basis of milling control and should be reported:

1.1 Moisture per cent bagasse

1.2 Imbibition water per cent fibre

1.3 Undiluted juice lost in bagasse per cent fibre

1.4 Mill extraction

1.5 Reduced mill extraction (f=12.5) for purposes of comparison with due appreciation of the fact that this does not allow for variations in fibre quality.

1.6 Whole Reduced Extraction (f=12.5 & p=12.5) for purpose of comparison with due appreciation of the fact that this does not allow for variation in fibre and sugar content.

1.7 Cane crushed per working hour.

In addition the following should also be determined and studied from time to time:

1.8 Preparation Index

1.9 Primary Extraction

1.10 Brix Curves

2. Process Control

The following control parameters are important:

2.1 Correct weights of mixed juice and imbibition water.

2.2 Brix and purity of filtered mixed juice, clear juice, filtrate, unsulphured & sulphured syrup etc.

2.3 Temperature, pH and visual clarity colour of clarified juice.

2.4 Weight and sugar content of filter cake and filter cake produced per cent cane.

2.5 Temperature and pH of sulphured syrup.

2.6 Brix and purity of each grade of massecuite and its light and/or heavy molasses as also the purities of magma and single/double cured B & C sugars.

2.7 Pol, moisture and quality (grain size and colour in solid state as well in solution) of white sugar.

2.8 Weight and purity of final molasses and final molasses produced per cent cane calculated.

2.9 Quantity of sugar produced and recovery of sugar per cent cane.

2.10 Boiling house efficiency indicators :

(a) Boiling House Recovery (BHR)

(b) Basic Boiling House Recovery (BHR with M=28.57)

(c) Overall Recovery

(d) Reduced Boiling House Recovery (ESG) Gundu Rao

(e) Reduced over-all Recovery.

2.11 Sugar, Brix and Non-sugar Balances.

Note : The sugar balance should based on sucrose in mixed juice, final molasses and sugar. The difference between pol and sucrose in cases of bagasse, filter cake and white sugar are neglected. Pol balance has to be regarded as approximate and useful for running control only.

3. Fuel and Steam Control

The following data should be reported:

3.1 Total fuel per cent cane in terms of standard bagasse of 45 per cent moisture (1 coal = 2.5 bagasse; 1 wood = 1.25 bagasse; 1 molasses = 1 bagasse; 1 furnace oil = 5 bagasse).

(For Heat value of bagasse, see Table VIII).

3.2 Steam generated % cane as measured by a steam flow meter.

3.3 Equivalent evaporation from and at 100°C (a) per kg of fuel (standard bagasse) (b) per sq.m. H.S. per hour.

3.4 Steam produced per kg of bagasse.

3.5 Heat balance of boilers.

CHAPTER – IX

CALCULATIONS

1.3 **Weight of bagasse :**

Weight of cane + Weight of added water – Gross weight of mixed juice.

1.4 **True average brix and pol of material :**

$$\frac{\text{Corrected brix x weight of the material}}{100}$$

Calculate the daily average for all the analyses of various materials.

The sum of these products divided by the total weight of the material and multiplied by 100 gives the true average brix of the material. The true average pol is calculated similarly.

1.5 **Tons Brix in mixed juice :**

$$\frac{\text{Brix \% mixed juice x Wt of mixed juice in tons}}{100}$$

1.6 **Tons Pol in mixed juice :**

$$\frac{\text{Pol \% mixed juice x Wt. of mixed juice in tons}}{100}$$

1.7 **Brix % bagasse :**

$$\frac{\text{Pol \% bagasse}}{\text{Purity of last expressed juice}} \times 100$$

1.8 **Fibre % bagasse :**

100 – Moisture % bagasse – Brix % bagasse

1.9 **Tons brix in bagasse :**

$$\frac{\text{Brix \% bagasse x Wt. of bagasse in tons}}{100}$$

1.10 **Tons Pol in bagasse :**

$$\frac{\text{Pol \% bagasse x Wt. of bagasse in tons}}{100}$$

1.11 **Tons Fibre :**

$$\frac{\text{Fibre \% bagasse x Wt. of bagasse in tons}}{100}$$

1.12 **Tons Moisture in bagasse :**

$$\frac{\text{Moisture \% bagasse x Wt. of bagasse in tons}}{100}$$

1.13 **Tons Brix in cane :**

Tons brix in mixed juice + Tons pol in bagasse

1.14 **Tons Pol in cane :**

Tons pol in mixed juice + Tons pol in bagasse

1.15 **Brix % cane :**

$$\frac{\text{Tons brix in cane}}{\text{Tons cane}} \times 100$$

1.16 **Pol % cane :**

$$\frac{\text{Tons pol in cane}}{\text{Tons cane}} \times 100$$

1.17 **Fibre % cane :**

$$\frac{\text{Tons fibre}}{\text{Tons cane}} \times 100$$

1.18 **Added water % fibre :**

$$\frac{\text{Added water \% cane}}{\text{Fibre \% cane}} \times 100$$

1.19 **Added water extracted in mixed juice % added water :**

$$\frac{\text{(Brix \% PJ - Brix \% MJ) x MJ \% Cane}}{\text{Brix \% PJ x Added Water \% Cane}}$$

(PJ = Primary juice, MJ = juice)

1.20 **Mixed juice % cane :**

$$\frac{\text{Tons mixed juice}}{\text{Tons cane}} \times 100$$

Imbibition water % cane, bagasse % cane, molasses % cane, filter cake % cane etc. are calculated similarly.

1.21 Absolute juice = cane – fibre

1.22 Java ratio = $\frac{\text{Pol \% cane}}{\text{Pol \% 1st expressed juice}} \times 100$

1.23 Milling ratio = $\frac{\text{Pol in mixed juice \% cane}}{\text{Fibre \% bagasse}} \times 100$

1.24 Dilution % primary juice to imbibition = $\frac{\text{Dilution \% primary juice}}{\text{Imbibition \% cane}}$

Where dilution % primary juice = $\frac{\text{Brix \% P.J. – Bx \% Mixed juice}}{\text{Bx \% Mixed juice}} \times 100$

If the ratio is below 0.95 the imbibition is too high, if above 1.05, imbibition is too low.

1.25 **Undiluted juice extracted % cane :**

$$\frac{\text{Brix \% mixed juice x mixed juice \% cane}}{\text{Brix \% primary juice}}$$

1.26 **Undiluted juice lost % fibre :**

$$\frac{\text{Brix \% bagasse x 10000}}{\text{Brix \% primary juice x Fibre \% bagasse}}$$

1.27 **Mill Extraction (e) :**

$$e = \frac{\text{Tons Pol in mixed juice}}{\text{Tons Pol in Cane}} \times 100$$

1.28 **Lost (absolute) juice % fibre (V) :**

$$V = \frac{(100 - e)\,(100 - f)}{f}$$

e = Recorded pol extraction

f = Fibre % cane

1.29 **Reduced Mill Extraction (Deerr) :**

$$E_{12.5} = 100 - \frac{(100 - e)\,(100 - f)}{7\,f}$$

where

$E_{12.5}$ = Reduced mill extraction

e = Recorded mill extraction

f = Fibre percent cane.

1.30 **Whole Reduced Extraction (Mittal) :**

(Reduced to 12.5% fibre and 12.5% pol in cane)

$$WRE = 100 - \frac{(100 - e) \times Pol\ \%\ cane}{Fibre\ \%\ cane}$$

(*Note :* The ISSCT has recommended that both the mill performance figures namely Reduced Mill Extraction (Deerr) and Whole Reduced Extraction (Mittal) should be reported.

1.31 **Primary extraction :**

1.31.1 Primary juice extraction

$$Brix\ \%\ primary\ bagasse = \frac{Pol\ \%\ primary\ bagasse}{Purity\ primary\ juice}$$

(*First mill discharge roll juice and first mill bagasse should be analysed, former for brix and pol and the latter for pol and moisture*)

Fibre % primary bagasse = [100 – (Moisture % PB + Brix % PB)]

(PB = primary bagasse)

$$Primary\ bagasse\ \%\ cane = \frac{Fibre\ \%\ Cane}{Fibre\ \%\ primary\ bagasse} \times 100$$

Primary juice extracted % cane =

$$\frac{(Fibre\ \%\ PB - Fibre\ \%\ cane)}{Fibre\ \%\ PB} \times 100$$

Absolute Juice % cane = 100 – Fibre % cane

Primary juice extracted % juice in cane =

$$\frac{Primary\ Juice\ extracted\ \%\ cane}{Absolute\ juice\ \%\ cane} \times 100$$

Example :

Pol % primary bagasse = 7.6

Moisture % primary bagasse = 55.2

First mill discharge roll juice

Brix = 18.39

Pol = 15.80

Purity = 84.29

Fibre % cane = 16.50

Calculation :

$$\text{Brix \% primary bagasse} = \frac{7.6}{84.29} \times 100 = 9.02$$

Fibre % primary bagasse = [100 – (55.2 + 9.02)] = 35.78

$$\text{Primary bagasse \% cane} = \frac{16.5}{35.78} \times 100 = 46.11$$

Primary juice % cane = 100 – 46.11 = 53.89

$$\text{Primary juice extracted \% juice in cane} = \frac{53.89}{100 - 16.5} = 64.54$$

1.31.2 Primary Pol extraction

Brix percent primary bagasse and Fibre percent primary bagasse to be found as given under 1.31.1.

Then fibre percent cane and Pol percent cane figures, average of the day or of the previous day should be taken from the factory daily report. Then,

$$\text{Primary bagasse \% cane} = \frac{\text{Fibre \% cane}}{\text{Fibre \% primary bagasse}} \times 100$$

Pol in primary bagasse % cane = Y

$$Y = \frac{\text{Pol \% primary bagasse x Primary bagasse \% cane}}{100}$$

Pol in primary juice % cane = Pol % cane – Y = Z

$$\text{Primary Pol extraction} = \frac{Z}{\text{Pol \% cane}}$$

Example :

If Pol percent cane is 13.0, then with the data as given under 1.31.1, the primary Pol extraction will calculate out as follows :

Primary bagasse % cane = 46.11

$$\text{Pol in primary bagasse\% cane} = \frac{7.6 \times 46.11}{100} = 3.50$$

Pol in primary juice % cane = 13.0 – 3.50 = 9.50

$$\text{Primary Pol extraction* } (e_p) = \frac{9.5}{13.0} \times 100 = 73.07$$

1.32 **Cane crushed per working hour :**

$$\frac{\text{Tons cane crushed}}{\text{Hours of actual crushing}}$$

1.33 **Molasses percent cane :**

Molasses percent cane in calculated on the weight of original molasses (analysis of the original molasses is to be given in the report). If dilution is employed before the molasses is weighed, it is converted into the weight of original molasses as follows :

$$\text{Tons brix in dil. molasses} = \frac{\text{Brix of dil. mol} \times \text{Wt. of dil. mol}}{100}$$

$$\text{Weight of original molasses} = \frac{\text{Tons brix in dil. mol}}{\text{Brix \% original Molasses}} \times 100$$

1.34 **Expected Recovery percent cane :**

$$\text{Sugar in clear juice \% cane} \times \frac{S(J - M)}{J(S - M)} - \text{Unknown loss \% cane}$$

Sugar in clear juice % cane = Sugar in mixed juice % cane – Sugar in filtercake % cane

Where S = Purity of Sugar = 100

J = Purity of clear juice

M = Purity of final molasses for the day

1.35 **Expected Molasses percent cane (Theoretical) :**

$$\frac{K \times \text{Mixed juice \% cane} \times (\text{Brix \% mixed juice} - \text{Pol \% mixed juice})}{(100 - m) \times \text{Average brix \% molasses}}$$

Where

K = non-sugars in clear juice % non-sugars in mixed juice

m = molasses purity for the day

1.36 **Equivalent evaporation percent cane :**

Equivalent water evaporated tons

$$= \text{Water evaporated tons} \times \frac{H - h}{539}$$

Where

H = total heat in steam from boilers in K Cal per kg.

h = total heat in feed water in K Cal per kg.

1.37 **Proportionate Purity Ratio or ERQV values :**

This value indicates loss of sugar, if any, due to microbiological activity or in other words it indicates the state of sanitation at the milling tandem.

It is calculated as follows :

1.37.1 $$\text{ERQV}\frac{MJ}{PJ} = \frac{\text{Available sugar \% brix in MJ}}{\text{Available sugar \% brix in PJ}} \times 100$$

$$= \frac{1.4\,(\text{Purity MJ} - 40)}{1.4\,(\text{Purity PJ} - 40)} \times 100$$

A value of about 98 indicates good sanitation.

1.37.2 $$\text{ERQV}\frac{LMJ}{PJ} = \frac{1.4\,(\text{Purity LMJ} - 40)}{1.4\,(\text{Purity PJ} - 40)} \times 100$$

A value of about 85 is considered satisfactory.

Note : As the purity of extracted juice decreases as pressure on the cane increases the following factors will influence ERQV values apart from chemical or biochemical loss.

(a) Pressure intensity applied on the mills configuration of the mills i.e. type of pressure feeding devices installed and number of mills employed. The greater the squeezing, the lower will be the ERQV value.

(b) Where primary juice represents a large proportion of the total extraction as when a smaller number of mills is employed, the value will tend to be high.

(c) The composition and characteristics of cane. Some canes will give low values of ERQV.

(d) For the same purity difference between PJ and MJ the value will depend upon purity level e.g. when PJ is 86 and MJ is 83, difference being 3, the ERQV value will be 94.79 but when PJ is 76 and MJ 73, the ERQV value is 93.67. It will thus be seen that a low value does not definitely indicate that there is inversion or biochemical loss at the mills.

2. Calculations for the run report :

(a) Average figure for the run or to-date should be based on the true averages.

(b) Before starting the run report, totals and averages register should be filled up to-date.

2.1 **Any Quantity for this Run** :

To-date figure on the last day of this run – To-date figure at the end of last run.

2.2 **Non-sugars in mixed juice :**

Tons brix in mixed juice – Tons sugar in mixed juice.

2.3 **Tons pol in clear juice :**

Tons pol in mixed juice – Tons pol in filter cake.

2.4 **Tons Brix in clear juice :**

$$\frac{\text{Tons Pol in clear juice}}{\text{Purity clear juice}} \times 100$$

2.5 **Tons non-sugar in clear juice :**

Tons brix in clear juice – Tons pol in clear juice.

2.6 **Non-sugars in clear juice per cent Non-sugars in mixed juice (k) :**

$$\frac{\text{Tons non - sugars in clear juice}}{\text{Tons non - sugars in mixed juice}} \times 100$$

2.7 **Clarification factor :**

100 – Non-sugars in clear juice per cent non-sugars in mixed juice.

Note : While judging the efficiency of clarification based on the above factor it should be borne in mind that :

(a) Densimetric brix of mixed juice is affected by suspended matter present in juice.

(b) Pol of clear juice by single polarisation is liable to be affected because of change in optical activity due to chemical reaction on reducing sugar present in juice.

2.8 **Tons clear juice :**

$$\frac{\text{Tons Pol in clear juice}}{\text{Pol \% clear juice}} \times 100$$

2.9 **Evaporation per cent clear juice :**

$$\frac{\text{Brix of syrup} - \text{Brix of clear juice}}{\text{Brix of syrup}} \times 100$$

2.10 **Total water evaporated :**

$$\frac{\text{Tons clear juice} \times \text{Evaporation \% clear juice}}{100}$$

2.11 **Evaporator efficiency :**

Kilograms water evaporated per sq.m of heating surface per working hour of the evaporator

$$\frac{\text{Tons clear juice x 1000 x Evaporation \% clear juice}}{100 \text{ x T x H}}$$

Where

T = hours evaporator worked, and

H = heating surface of the evaporator in sq m.

2.12 **Total sugar production**

(a) To-date

Sugar bagged (to-date) + sugar in process – sugar recovered from reprocessing of last year's material = X (say)

(b) For the run

Suppose the to-date sugar production at the end of previous run = Y

Sugar produced in the run = X – Y.

2.13 **Recovery per cent cane :**

$$\frac{\text{Tons sugar}}{\text{Tons cane}} \times 100$$

2.14 **Total molasses production :**

(a) To-date

Molasses sent out + Molasses in process – Molasses produced from last year's sugar (brown or/and damaged) = P (say)

(b) For the run

Suppose the to-date molasses production at the end of previous run = Q

Molasses produced in this run = P – Q

2.15 **Molasses per cent cane :**

$$\frac{\text{Tons molasses}}{\text{Tons cane}} \times 100$$

2.16 **Non-sugar in molasses :**

Tons brix in molasses – Tons sugar in molasses

2.17 **Non-sugar in molasses per cent non-sugar in mixed juice :**

$$\frac{\text{Tons brix in molasses} - \text{Tons sugar in molasses}}{\text{Tons brix in mixed juice} - \text{Tons sugar in mixed juice}} \times 100$$

2.18 **Theoretical quantity of molasses :**

$$\frac{\text{Tons non-sugar in clear juice x Tons molasses}}{\text{Tons non-sugar in molasses}}$$

2.19 **Molasses actually produced percent theoretical :**

$$\frac{\text{Tons molasses produced}}{\text{Tons theoretical molasses}} \times 100$$

2.20 **Sugar (ESG) :**

$$\text{Sugar in sugars produced x } \frac{100(S-M)}{S(100-M)}$$

Where

S = Purity of sugar produced

$$= \frac{\text{Sugar \% sugar produced}}{100 - \text{Moisture \% sugar produced}} \times 100$$

M = Gravity purity of final molasses

2.21 **Boiling House Recovery :**

$$\frac{\text{Sucrose (or Pol) in sugar produced}}{\text{Sucrose (or Pol) in mixed juice}} \times 100$$

2.22 **Basic Boiling House Recovery :**

$$\text{BHR (Basic)} = \frac{S(J-M)}{J(S-M)} \times 100$$

Where

S = Purity of final product = 100

J = Recorded gravity purity of mixed juice

M = 28.57

2.23 **Boiling House Recovery Factor :**

$$\frac{\text{Recorded BHR}}{\text{Theoretical BHR by SJM}}$$

In which J is the recorded mixed juice purity and M is the recorded final molasses purity.

2.24 **Equivalent Standard Granulated :**

ESG = Quantity of dry pure sucrose theoretically obtainable from commercial sugar using SJM formula in which S = 100.

J = Purity of commercial sugar and

M = Recorded gravity purity of final molasses

2.25 **Boiling House Recovery (ESG)** :

$$\text{BHR (ESG)} = \frac{\text{Sucrose in sugar}}{\text{Sucrose in mixed juice}} \times 100 \times \frac{100(J-M)}{J(100-M)}$$

Where J is the purity of commercial sugar and M is actual purity of molasses.

2.26 **Boiling House Performance :**

$$\text{BHP} = \frac{\text{BHR(ESG)}}{\text{Basic BHR}} \times 100$$

2.27 **Overall Recovery or Overall Extraction :**

$$OR \text{ or } OE = \frac{\text{Sucrose (or Pol) in sugar produced}}{\text{Sucrose (or Pol) in cane}} \times 100$$

2.28 **Reduced Boiling House Recovery (ESG) Deerr (R85) :**

$$R\,85 = \frac{100\,(85 - M_v)}{85\,(100 - M_v)} \times 100$$

Where Mv is the vartual purity of the final molasses and is given by the expression :

$$Mv = \frac{J - rJ}{1 - rJ}$$

where J = Gravity purity of mixed juice

r = BHR (ESG)

2.28.1 **Reduced Boiling House Recovery (ESG) Gundu Rao (R85) :**

$$R\,(85) = r + K\frac{M}{1-M} \times \frac{(17 - 20J)}{17J}$$

Where r = Recorded boiling house recovery.

K = Non-sugars in clear juice % non-sugars in mixed juice.

M = Actual gravity purity of final molasses.

J = Gravity purity of mixed juice.

Values of the factor $\frac{17 - 20J}{17J}$ are given for, various values of J from 75–95, in Table No. 11 given below :

Table No. 11

J	$\frac{17 - 20J}{17J}$	J	$\frac{17 - 20J}{17J}$	J	$\frac{17 - 20J}{17J}$
75	+ 0.1568	82	+ 0.0430	89	– 0.0529
76	+ 0.1393	83	+ 0.0283	90	– 0.0654
77	+ 0.1222	84	+ 0.0140	91	– 0.0776
78	+ 0.1055	85	0.0000	92	– 0.0895
79	+ 0.0893	86	– 0.0137	93	– 0.1012
80	+ 0.0735	87	– 0.0270	94	– 0.1126
81	+ 0.0581	88	– 0.0401	95	– 0.1238

2.29 **Reduced Overall Recovery (ESG) :**

$$\frac{\text{Reduced mill extraction (e 12.5) x Reduced boiling house recovery (r.85)}}{100}$$

2.30 **Bagasse burnt in terms of standard bagasse of 45 percent moisture :**

$$\frac{\text{Heat value of one kilogram of bagasse actually burnt}}{\text{Heat value of one kilogram of 45\% moisture bagasse}} \text{ x Tons bagasse}$$

(*See* Reference Table No. VIII-A).

2.31 **Total fuel burnt in terms of Standard Bagasse of 45 percent moisture :**

Bagasse burnt converted into standard bagasse + All other fuel converted into standard bagasse.

1 coal = 2.5 bagasse; 1 wood = 1.25 bagasse, 1 molasses = 1 bagasse; 1 furnace oil = 5 bagasse.

2.32 **Equivalent Evaporation :**

Water evaporated from and at 100°C

$$\text{Water evaporated x } \frac{H - h}{539}$$

Where

H = Total heat in steam issuing from the boilers in K Cal per kg and

h = Total heat in feed water in K Cal per kg.

2.33 **Equivalent Evaporation percent Cane**

$$\frac{\text{Equivalent evaporation tons}}{\text{Tons cane}} \text{ x } 100$$

2.34 **Equivalent Evaporation per kg of Standard Bagasse :**

$$\frac{\text{Equivalent evaporation tons}}{\text{Tons of bagasse of 45\% moisture}}$$

2.35 **Equivalent Evaporation per sq. m. of boiler heating surface per hour :**

$$\frac{\text{Total equivalent evaqporation in kg.}}{\text{Total heating surface of boilers in operation in sq m x Number of hrs. worked}}$$

2.36 **Steam obtainable per kg of bagasse :**

For fuel control purposes, it is necessary to work out the quantity of steam which can theoretically be obtained from the combustion of a known weight of bagasse and that actually obtained under the working conditions of the factory.

Steam theoretically obtainable can be calculated out on the basis of the following data :

i) *Fuel value of bagasse*

ii) *Products of combustion obtainable*

iii) *Heat lost through them*

iv) *Heat utilised in the production of steam.*

i) *Fuel value of bagasse :*

An average value of 4640 K. Cal per kg of bone dry bagasse may be taken.

ii) *Products of Combustion :*

The composition of dry bagasse may be taken as

Carbon = 46.5%

Hydrogen = 6.5%

Oxygen = 46.0%

$C + O_2 = CO_2$

12 + 32 = 44.0

That is, per kg of carbon, oxygen required will be

32/12 = 2.67, and

CO_2 will be 44/12 = 3.67

Per kg of hydrogen, oxygen required to form water will be:

$H_2 + O = H_2O$

2.016 + 16 = 18.016 or

Per kg of hydrogen, oxygen required will be

16/2.016 = 7.93 and

H_2O formed will be 8.93 kg.

One kg of dry bagasse of the above composition will then require

0.465 x 2.67 + 0.065 x 7.93 = 1.75 kg oxygen.

As the bagasse already contains 0.46 oxygen, it will be necessary to supply for complete combustion 1.75 – 0.46 = 1.29 kg of oxygen by way of air.

As oxygen in air is 23 percent by weight 1.29 kg of oxygen will come from 5.6 kg of air and the products of combustion from 1 kg of dry bagasse will be :

Due to Carbon

0.465 x 3.67 = 1.70 kg of CO_2

Due to Hydrogen

0.65 x 8.93 = 0.58 kg of H_2O

If air has 1 percent moisture, 0.56 kg air will contain 0.056 kg H_2O, and total H_2O will be 0.58 + 0.056 = .636 kg.

Nitrogen introduced with air will be 5.6 x 0.76 = 4.256 kg (nitrogen being 76 percent by weight of air).

As excess air has to be used for ensuring proper combustion, the various products of combustion with 50 per cent, 75 per cent and 100 percent excess air will be as follows :

with excess air, quantities of water, nitrogen and oxygen will increase.

With 50 per cent excess, the air quantity will be

5.6 + 2.8 = 8.4 kg.

Moisture will be = 0.084

and total H_2O will be = 0.58 + .084 = 0.664

Increased quantities of nitrogen and oxygen can be calculated similarly. The position with 50 percent, 75 percent and 100 percent excess air will be as follows :

Products	**Excess Air**			
	None	**50%**	**75%**	**100%**
CO_2	1.700	1.700	1.700	1.700
Water	0.636	0.664	0.678	0.692
Nitrogen	4.256	6.384	7.448	8.512
Oxygen	–	0.644	0.966	1.288

If bagasse contains 45 percent moisture, that is, 55 percent dry matter

Carbon will be 0.465 x 0.55 = 0.256

Hydrogen will be 0.065 x 0.55 = 0.357

Oxygen will be 0.46 x 0.55 = 0.253

Now carbon to form CO_2 will require 0.256 x 7.93 oxygen

Hydrogen to form water will require 0.357 x 7.93 = 0.283 oxygen

Total oxygen required will be 0.683 + 0.283 = 0.966 kg.

0.253 Oxygen is already present, that from air will have to be

0.966 – 0.253 = 0.713, which will come from $\frac{0.713 \times 100}{23}$ = 3.1Kg air.

Then products of combustion as calculated in the case of dry bagasse with 50 percent, 75 percent and 100 percent excess air for 45 percent moisture bagasse will be as follows :

Products	Excess Air			
	None	50%	75%	100%
CO_2	0.940	0.940	0.940	0.940
Water	0.800	0.816	0.824	0.832
Nitrogen	2.360	3.534	4.122	4.712
Oxygen	–	0.356	0.534	0.713

Theoretical quantity of steam obtainable from bagasse having 45 percent moisture, may be calculated as follows :

On the basis of air at 27°C and flue gas temperature of 260°C, the steam available (from and at 100°C) can be worked out.

It is accepted that each kg of water present in the flue gas whether due to associated water or combined water abstracts 694 K. Cal of heat and each kg of gas, whether CO_2 or nitrogen or oxygen, abstracts 55.56 K. Cal of heat.

Then heat lost due to associated water will be 0.45 x 694 = 312 K. Cal; that due to combined water 0.32 x 694 = 222 K. Cal.

With 50 percent excess air, heat loss in gases will be,

CO_2	=	0.94
N	=	3.53 (*See* table above)
O	=	0.36
Total		4.83 x 55.56 = 268 K. Cal

Total heat loss, in water and gases will be

312 + 222 + 268 = 802 K. Cal

With 75 percent excess air, gases are

CO_2	=	0.940
N	=	4.122
O	=	0.534
Total		5.596

Heat loss will be 5.596 x 55.56 = 311 K. Cal and total loss in flue gas will be

312 + 222 + 311 = 845 K. Cal

With 100 percent excess air

CO_2	=	0.940
N	=	4.712
O	=	0.713
Total		6.365 x 55.56 = 354 K. Cal.

Total Loss = 312 + 222 + 354 = 888 K.Cal.

Now fuel value of bone dry bagasse may be taken as 4640 K. Cal, that for 45 percent moist bagasse, or 55 percent dry matter will be 4640 x 0.55 = 2552 K. Cal.

Then heat available for steam production in the above cases viz., 50, 75, 100 percent excess air, will be*

50% excess air = 2532 – 802 = 1750 K. Cal.

75% excess air = 2532 – 845 = 1707 K. Cal.

100% excess air = 2532 – 888 = 1664 K. Cal.

Now latent heat of steam being 539 K. Cal, steam obtainable per kg of bagasse will be respectively.

1750/539 = 3.23 kg

1707/539 = 3.17 kg

1664/539 = 3.08 kg.

2.37 **Heat balance of boilers :**

(i) Heat obtained from burning bagasse in the boiler should be accounted for against the heat utilisation in the production of steam, (ii) heat lost in flue gases,

* Calculation can be made for any quantity of excess air on similar lines.

(iii) sensible heat lost in the ash, (iv) heat lost in unburnt material and (v) other miscellaneous losses such as incomplete combustion, radiation etc.

The heat value of wet bagasse may be calculated from the following formula :

NCV = 4250 – 12S – 48.5 W

where S = sucrose % bagasse and W = moisture % bagasse

NCV = Net Calorific Value.

Boiler Efficiency (BE):

This is the ratio of heat utilised for the production of steam to that available from the combustion of bagasse. It may be calculated on the lines of the following example;

Data

i) Bagasse burnt = 100000 Kg.

ii) Sugar % bagasse = 3.00

iii) Moisture % bagasse = 50.00

Then NCV = 4250 – (12 x 3) – (48.5 x 50)

= 4250 – 36 – 2425

= 1789 K. Cal/Kg.

iv) Steam produced = 200000 Kg.

v) Pressure of steam = 20 Kg./cm^2

vi) Temperature of steam = 320°C (Total heat 732.6 K. Cal/Kg.)

vii) Temp. of feed water = 90°C

viii) Blow down 1.0 percent of steam produced, having a temperature of 235°C (Total heat 684 K. Cal/Kg.)

(a) Total amount of heat available = 100000 x 1789

= 1789 x 10^5 K. Cal

(b) Heat utilized in the production of steam = 200000 x 732.6

= 1465 x 10^5 K. Cal

(c) Heat in blow down (one per cent)

$$\frac{(684 \times 200000 \times 1)}{100} = 13.7 \times 10^5 \text{ K. Cal}$$

(d) Heat in feed water = $(200000 + 2000) \times 90$

= 182×10^5 K cal

Heat transmitted = (b+c–d) = $(1465 + 13.7 - 182) \times 10^5$ K. Cal

= 1296.7×10^5 K. Cal

Heat available = 1789×10^5 K. Cal

$$\therefore \text{ Boiler Efficiency} = \frac{1296.7 \times 10^5}{1789 \times 10^5} \times 100$$

$$= 72.48$$

Note : Boiler efficiency based on GCV can be obtained by multiplying BE (NCV) by the quality factor of bagasse *viz.*, 0.79.

Thus BE (GCV) in the above example would be = 72.48 x 0.79

= 57.26

Heat Balance :

Heat available from bagasse = Heat recovered in steam + heat lost in various ways.

Heat losses may be calculated as follows :

(a) Sensible heat lost in flue gases :

This can be derived from the following formula :

$q = [(1 - w)(1.4m - 0.13) + 0.5]t$*

Where q is the sensible heat lost in flue gases in K. Cal/kg.

t is the temperature of flue gases in °C above room temp.

w is the moisture per unit bagasse

m is the ratio of weight of air used from combustion to the weight theoretically necessary.

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* Handbook of Cane Sugar Engineering, E. Hugot, III Ed., Page 936.

Let m = 1.5; w = 0.50 and t = 250°C

The q = 250 [(0.5) (1.4 x 1.5 – 0.13) + 0.5]

= 250 [(0.5 x 1.97) + 0.5]

= 250 [0.985 + 0.5] = 250 x 1.485

= 371.25 K. Cal/Kg of bagasse as from 0°C.

In the above example

$$q = 100000 \times 371.25 = 371.25 \times 10^5 \text{ K. Cal}$$

$$\text{or } \frac{371.25}{1789} \times 100 = 20.75\% \text{ of NCV}$$

(b) Losses due to unburnt material + radiation + incomplete combustion may be computed as follows :

Heat still remaining to be transferred x $\alpha\ \beta\ \chi$

Where α = Coefficient of loss by unburnt solids

β = Coefficient of loss due to radiation and convection

χ = Coefficient of loss due to incomplete combustion

These may be assumed to be as follows :

$\alpha = 0.97$ $\beta = 0.99$ and $\chi = 0.96$ under average operating conditions.

Thus $\alpha\ \beta\ \chi = 0.97 \times 0.99 \times 0.96 = 0.922$

Heat remaining to be transferred = Total heat available minus heat transmitted to steam minus heat lost in flue gases, *i.e.*

$(1789 - 1296 - 371.25) \times 10^5 = 121.75 \times 10^5$ K. Cal

Losses due to unburnt, radiation and incomplete combustion

$= 121.75 \times 10^5 \times 0.922 = 112.25 \times 10^5$ K. Cal

Heat balance will thus be as follows :

i)	Heat from bagasse = 1789 x 10^5 K. Cal	= 100.00
ii)	Heat transferred to steam = 1296 x 10^5 K. Cal	= 72.48
iii)	Heat in flue gases = 371.25 x 10^5 K. Cal	= 20.75
iv)	Heat in unburnt etc. = 112.25 x 10^5 K. Cal	= 6.24
v)	Unaccounted miscellaneous loss $(1789 - 1296 - 371.25 - 112.25) \times 10^5 = 9.5 \times 10^5$	= 0.53
	Total (ii + iii + iv + v)	= 100.00

2.38 Pol, Brix and Non-sugar balances :

In accordance with pol input, pol recovered and pol lost, a pol balance can be written as shown in the following example :

2.38.1 *Pol balance*

(a)	Pol % cane	=	12.50
(b)	Pol in mixed juice % cane	=	11.60
(c)	Pol in bagasse % cane	=	0.90
(d)	Pol in filter cake % cane	=	0.07
(e)	Pol in molasses % cane	=	1.33
(f)	Sugar in sugar % cane	=	10.10
(g)	Undetermined loss % cane	=	0.10
	Total loss	=	2.40

The "undetermined" or unaccounted loss may be due to any or some of the following factors :

(a) Incorrect weighment

(b) Wrong sampling, or analysis

(c) Inversion or caramelisation of sucrose, *i.e.,* chemical loss.

(d) Leakage or spillage of sugar bearing material or entrainment *i.e.* physical or mechanical loss.

A clear picture about the nature of loss incurred can be had if Brix and Non-sugar balances are also drawn up as indicated in the example given below :

2.38.2 *Brix balance* :

	Quantities	**Tons**	**Percent cane**
(a)	Cane crushed	30000	–
(b)	Mixed juice (MJ)	25500	85.00
(c)	Filter cake (FC)	900	3.00
(d)	Final molasses (FM)	1350	4.50
(e)	Sugar	2940	9.80

	Analysis	Brix	Pol	Purity	Moisture
(a)	Mixed juice	18.00	15.00	83.33	–
(b)	Clear juice (CJ)	18.84	15.80	83.86	–
(c)	Final molasses	92.00	33.12	36.00	–
(d)	Filter cake	–	2.50	–	–
(e)	Commercial sugar	–	99.80	–	0.05

Pol in MJ % cane $= \frac{15 \times 85}{100} = 12.75$

Pol in FC % cane $= \frac{3 \times 2.5}{100} = 0.075$

$\therefore$ Pol in CJ % cane = Pol in MJ % cane – Pol in FC % cane

$= 12.75 - 0.075 = 12.675$

Brix in CJ % cane $= \frac{\text{Pol in CJ \% cane}}{\text{Purity CJ}} \times 100$

$= \frac{12.675}{83.86} \times 100 = 15.11$

Brix in final mol. % cane $= \frac{\text{Bx \% FM x FM \% cane}}{100}$

$= \frac{92 \times 4.5}{100} = 4.14$

Brix in Sugar % cane $= \frac{\text{Bx \% Sugar x Sugar \% cane}}{100}$

$= \frac{99.95 \times 9.8}{100}$

$= 9.795$

Total Brix accounted for $= 4.14 + 9.795 = 13.935$

Brix in CJ % cane $= 15.110$

Brix accounted for $= 13.935$

Loss $= 1.175$

This indicates a mechanical loss. If the brix accounted for was higher than the brix in clear juice, it would indicate wrong weighment or analysis of mixed juice, final molasses etc.

2.38.3 *Non-sugar balance*

a) Non-sugar in clear juice percent cane

= Brix in clear juice % cane – Pol in CJ% cane

= 15.11 – 12.675 = 2.435

b) Non-sugar in sugar % cane :

= Brix in sugar % cane - Pol in sugar % cane

$$= \frac{\text{Brix \% x recovery \% cane}}{100} - \frac{\text{Pol \% x Recovery \% cane}}{100}$$

$$= \frac{(100 - 0.05) \times 9.8}{100} - \frac{99.8 \times 9.8}{100}$$

= 9.795 – 9.780 = 0.015

c) Non-sugar in final molasses % cane :

= Brix in final molasses % cane – Pol in FM % cane

$$= \frac{\text{Brix \% FM x FM \% cane}}{100} - \frac{\text{Pol \% FM x FM \% cane}}{100}$$

$$= \frac{92 \times 4.5}{100} - \frac{33.12 \times 4.5}{100}$$

4.14 – 1.49 = 2.65

Now (b) + (c) = 0.015 + 2.65 = 2.665

There is a gain in non-sugar which indicates chemical decomposition or wrong analysis of molasses. If there was a loss it would indicate mechanical loss.

For proper investigation, sucrose or preferably crystal and reducing sugars balances should be drawn after determining the same in clear juice, sugar and final molasses.

2.39 **Conversion of raw-sugar recovery into equivalent white commercial sugar recovery :**

The procedure to calculate equivalent white sugar recovery from the raw sugar recovery is given below :

$$\text{ESG} \quad P \times \frac{S\,(J - M)}{J\,(S - M)}$$

Where ESG = Equivalent Standard Granulated

P = Pol % sugar

S = 100

M = purity of final molasses

$$J = \text{Purity of sugar} = \frac{\text{Pol \% sugar}}{100 - \text{Moisture \% sugar}} \times 100$$

$$\text{Recovery White Sugar} = \frac{\text{ESG Raw Sugar x Recovery Raw Sugar}}{\text{ESG White Sugar}}$$

Example :

Pol % raw sugar = 97.8

Moisture % raw sugar = 0.44

$$\text{Purity raw sugar} = \frac{97.8 \times 100}{100 - 0.44} = 98.23$$

Pol % white sugar = 99.8

Moisture % white sugar = 0.05

$$\text{Purity of white sugar} = \frac{99.8 \times 100}{100 - 0.05} = 99.85$$

Purity of final molasses = 35.00

Recovery % raw sugar = 10.00

$$\text{ESG Raw Sugar} = 97.8 \times \frac{100\,(98.23 - 35)}{98.23\,(100 - 35)} = 96.8$$

$$\text{ESG White Sugar} = 99.8 \times \frac{100\,(99.85-35)}{99.85\,(100-35)} = 99.72$$

$$\text{Recovery White Sugar} = \frac{96.85 \times 10}{99.72}$$

$$= 9.712$$

Thus if the recovery of raw sugar of 97.8 pol is 10.00 per cent on cane, the equivalent recovery in terms of commercial white sugar of 99.8 pol would be expected to be 9.712 per cent.

CHAPTER – X

STOCK TAKING

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STOCK TAKING

When the processing is stopped at the end of a run or for any other reasons large quantities of juice, syrup, molasses and massecuites, etc. remain in process. It is of great importance that the quantities of these as well as their recoverable sugar contents are estimated accurately to verify the house position in accordance with the recovery.

Weights of material in process are calculated from volumetric measurements. To enable this to be done rapidly, all vessels should be calibrated and their cubical contents at each metre of the height should be calculated and tabulated for ready reference. Volume occupied by the material = Total volume of the vessel – volume of unoccupied space.

At the time of volumetric measurement, the temperature of the material in the vessel should also be recorded.

1. **For Juices and Syrup :**
   The brix of juices should be spindled without dilution, whereas, in case of syrup minimum dilution should be resorted to. The observed brix is corrected for the spindling temperature (table IV-A of IV-B). From the corrected brix so obtained, the uncorrected brix at the temperature of the stock material (at the time of measuring its volume) is computed. The corresponding specific gravity is read out from the Table III-A or III-B.

   Weight of Stock = Volume of stock x specific gravity at t^0/t^0C x Wt of water per unit volume at standard temperature.

   Note : t = 20^0C or 27.5^0C (according to the standard temperature adopted).

2. **For Massecuites and Molasses :**
   The weight per unit volume should be determined directly by filling a bottle or wooden box of known volume with the material and weighing it, taking care that there is no appreciable cooling in the process. From the weight per unit volume thus found and the actual volume measured, the weight of material is calculated.

   If weights are calculated on the basis of diluted samples, suitable correction factors must be applied. The amount of correction to be applied should be determined experimentally at each factory for the different products and conditions.

   On the basis of analysis, tons brix and tons pol or sucrose in material are then calculated.

3. **Available Sugar**
   Calculation for finding out available sugar should be based on gravity purities and **s-j-m** formula. Where the pol basis of control is in use, all purities in the formula should be apparent purities.

3.1 **Available Sugar in Material**

$$\text{Tons sugar in material} - \frac{M}{100 - M} \times (\text{Tons brix in material} - \text{Tons sugar in material})$$

Where

M = average purity of final molasses sent out during the run.

3.2 **Calculated Available Sugar in Process**

Sum of available sugar from all the materials in process.

3.3 **Actual Available Sugar :**

Calculated available sugar – Total undetermined sugar loss

Where

Total undetermined sugar loss

$$= \frac{\text{Average undetermined loss \% sugar x tons sugar in material}}{100}$$

3.4 **Molasses in Process**

$$= \frac{(\text{Total Bx in process} - \text{Total actual available sugar})}{\text{Average Bx \% Molasses}} \times 100$$

Example

(i) Syrup :

Tank dimension - Length - 2m

Breadth - 2m

Height - 1.25 m

$\therefore$ Tank capacity = 2 x 2 x 1.25 = 5 cu m

I cm height of tank = 0.04 cu m

Syrup is full upto 1.00 in level

$\therefore$ Volume of syrup in the tank = 4 cu m

Temperature of Syrup = 50^0C

Analysis of syrup :	Bx %	Pol %	Purity
	55.0	46.75	85.0

Uncorrected brix corresponding to 50^0 C

55 – 2.57 = 52.43

Corresponding sp. gravity = 1.24524

$\therefore$ Weight of syrup = 4 x 1.24524 x 1 = 4.981 tons

(weight of 1 cu m of water 1.0 ton)

$$\therefore \text{ Total Brix} = \frac{4.981 \times 55}{100} = 2.740 \text{ tons}$$

$$\text{Total Sugar} = \frac{4{,}981 \times 46.75}{100} = 2.329 \text{ tons}$$

$\therefore$ Total non sugars = 2.740 – 2.329 = 0.411 ton

Average molasses purity for the run = 33.33

$$\therefore \frac{m}{100 - m} = \frac{33.33}{100 - 33.33} = 0.5$$

Hence available sugar = 2.329 – 0.411 x 0.5 – 2.329 – 0.2055 = 2.1235

Average under terminated loss = 1% on sugar

$$\therefore \text{ Total undetermined sugar loss} = \frac{1}{100} \times 2.329 = 0.0233 \text{ ton}$$

$\therefore$ Actual available sugar = 2.1235 – 0.0233 = 2.1002 tons

(ii) Massecuite :

Crystalliser Capacity = 18.4 cu m

One cm height of crystalliser = 0.1114 cu m

Massecuite is full upto 25 cm less from top of the crystalliser

Volume of massecuite = 18.4 – (25 x 0.1114)

= 18.4 – 2.785

= 15.615 cu m

Bx of massecuite = 95.8

Weight of 1 cu m of massecuite = 1.51 tons

∴ Wt of massecuite = 15.615 x 1.51 = 23.58 tons

Further calculations are similar to those given for syrup

An actual calculation is given in the statement on the next page.

WEEKLY STOCK CALCULATION

Analysis of weekly final molasses sample : Brix-97.67 : Pol-36.08 : Purity-36.94

$$\text{Molasses Factor} = \frac{m}{100 - m} \text{ where m is molasses purity}$$

$$= \frac{36.94}{63.06} = 0.59$$

a.	Material	Juice	Syrup	Melt	A Masecuite	B Massecuite	C Massecuite	A/L Molasses	A/H Molasses	C/L Molasses	B/H Molasses	Sugar	Molasses
b.	Cu. ft.	8438	1511	–	1587	2278	3700	294	629	728	708	–	–
c.	Cu. Meter	238.96	42.79	–	44.94	64.51	104.78	8.33	17.81	20.62	20.05	–	–
d.	Sp. gr. at 20°C/20°C	10.06	1.26	–	1.51	1.53	1.56	1.39	1.42	1.41	1.49	–	–
e.	c x d x 10 wt. of material in qtls.	2532.76	539.15	–	678.59	987.00	1634.57	115.79	252.90	290.74	298.75	–	–
f.	**Material**												
	(i) Brix	14.59	55.43	–	93.22	96.01	101.30	76.20	80.37	79.37	91.40	–	–
	(ii) Pol	11.83	47.15	–	83.83	70.59	61.25	70.20	61.33	48.43	49.03	–	–
	(iii) Purity	81.08	85.06	–	89.93	73.52	60.46	92.13	76.31	61.02	53.64	–	–
g.	$\frac{e \times f\,(i)}{100}$ Total Bx. in qtls.	369.53	298.85	–	632.58	947.62	1655.82	88.23	203.26	230.26	273.06	–	–
h.	$\frac{e \times f\,(ii)}{100}$ Total Pol in qtls.	299.63	254.21	–	568.86	696.72	1001.17	81.28	155.10	140.81	146.48	–	–
i.	g – h (Bx. – Pol) qtls.	69.90	44.64	–	63.72	250.90	654.65	6.95	48.16	89.95	126.58	–	–
j.	i x factor (Bx. – Pol) x 0.59 qtls.	41.24	36.34	–	37.59	148.03	386.24	4.10	28.41	53.07	74.68	–	–
k.	h – j available sugar qtls.	258.39	217.87	–	531.27	548.69	614.93	77.18	126.69	87.74	71.80	–	–

l.	1% unknown loss of h qtls.	3.00	2.54	–	5.69	6.97	10.01	0.81	1.55	1.41	1.46	–	–
m.	K – L actual available sugar qtls.	255.39	215.33	–	525.58	541.72	604.92	76.37	125.14	86.33	70.34	–	–
n.	g – m balance solids (Brix) to molasses qtls.	114.14	83.52	–	107.00	405.90	1050.90	11.86	78.12	144.13	202.72	–	–
o.	n x 100 / in Bx. molasses, (97.67) or, Actual moll. produced qtls.	116.86	85.51	–	109.55	415.58	1075.97	12.14	79.98	147.88	207.56	–	–
p.	Loose sugar/Molasses	–	–	–	–	–	–	–	–	–	–	261.00	–
q.	Total in process (m + p)	–	–	–	–	–	–	–	–	–	–	2762.12	2251.03
r.	Sample sugar	–	–	–	–	–	–	–	–	–	–	0.03	–
s.	Weighed quantity	–	–	–	–	–	–	–	–	–	–	30800.00	12989.29
t.	Total production (s + q + r)	–	–	–	–	–	–	–	–	–	–	33562.15	15240.32
u.	Less last year's reprocessed	–	–	–	–	–	–	–	–	–	–	1410.19	355.07
v.	Total production to date (t – u)	–	–	–	–	–	–	–	–	–	–	32151.96	14885.25
w.	Less last week's todate	–	–	–	–	–	–	–	–	–	–	24709.88	11573.09
x.	Production for the week (v – w)	–	–	–	–	–	–	–	–	–	–	7442.08	3312.16

CHAPTER – XI

SYSTEM OF RECORDING AND REPORTING CONTROL DATA

CHAPTER – XI

SYSTEM OF RECORDING AND REPORTING CONTROL DATA

For evaluating the performance of a cane sugar factory the following controls have to be exercised.

(a) **Cane weight control :** This is concerned with supervising the weighing operations so as to ensure the accuracy of the cane weight which is the starting point of all the controls involved in sugar factory operation.

(b) **Running control :** The object of this is to carry out all the necessary determinations of quantities and analyses of the raw material, intermediate products, final products and byproducts and utilising the data so obtained for working out the various control parameters.

(c) **Accounting control :** This is meant to draw up a balance sheet of the sugar imported through the sugarcane crushed and its distribution in the various intermediate and final products.

(d) **Efficiency control :** This relates to working out various efficiency criteria from the data obtained under accounting control so as to evaluate the performance of the factory in regard to its own working as well as to compare its performance with that of the other factories.

Specimen forms in which the various control data may be recorded and reported are appended herewith. These are only indicative and may be amended according to specific requirements. Based on it, total and averages record tables for sugarcane, mixed juice, bagasse, final molasses and press cake etc. may be prepared.

DAILY ANALYSIS RECORD

Season.....

Date.....

Crop Day.....

	Primary Juice			Mixed Juice			Last Mill Juice			Clarified Juice			Filtered Juice			Clarified Filtered Juice After ECS)			Final Molasses			Bagasse		Press cake
	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Pol %	Moisture	Pol %
Average																								

	Unsulphured Syrup			Sulphured Syrup			Clarified Syrup			A – Massecuite				B – Massecuite				C1 – Massecuite				C – Massecuite			
	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Lot. No. Time	Bx.	Pol.	Py.	Lot. No. Time	Bx.	Pol.	Py.	Lot. No. Time	Bx.	Pol.	Py.	Lot. No. Time	Bx.	Pol.	Py.
Average																									

	A – Heavy			A – Light			B – Heavy			C1 – Heavy			C – Light			Final Molasess		
	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.
Average																		

	A Magma			B Magma			C Magma			Purity		Melt			Seed		
	Bx.	Pol.	Py.	Bx.	Pol.	Py.	Bx.	Pol.	Py.	B Cured Sugar	C Double Cured Sugar	Bx.	Pol.	Py.	Bx.	Pol.	Py.
Average																	

	KEY SAMPLE	SPECIAL ANALYSIS	REMARKS
	Analyst Shift A	Analyst Shift B	Analyst Shift C

Lab. Incharge

Chief Chemist

DAILY MANUFACTURING REPORT

Season _____ _____

Name of the Factory _____ Installed Capacity _____ TCD

Date _____ Day from _____ A.M. of _____

This Year _____ Last Year _____ To _____ A.M. of _____

Report No. _____

	CANE CRUSHED (QTLS)		SUGAR BAGGED (QTLS)		SUGAR RECOVERY % CANE		HOURS WORKED		HOURS LOST		CRUSHING RATE ON 24 HRS. INCL. STOPP (QTLS)	
	This Year	Last Year	This Year	Last Year	This Year	Last Year	This Year	Last Year	This Year	Last Year	This Year	Last Year
On Date												
To Date												

PARTICULARS	THIS YEAR		LAST YEAR		Sl.	TECHNICAL CONTROL DATA		LABORATORY ANALYSIS			
	On Date	To Date	On Date	To Date		Particulars	This Year	Particulars	Bx	Pol	Purity
CANE					1.	Gross Capacity utilisation on date		Primary Juice			
1. Cane per Tank					2.	- do - to date		Mixed Juice			
2. Sugar %					3.	Cane Crushed / 24 Hrs Excluding Stoppages i) On date (Qtls) ii) To date (Qtls)		Last Mill Juice			
3. Fibre %								Clarified Juice			
MACERATION					4.	Gross Capacity utilisation % to date (LAST YEAR)		Filtered Juice			
								Treated Filtered Juice (after FCS)			
1. % Cane					5.	Mill Extraction		Ulsulphured Syrup			
2. % Fibre					6.	i) Reduced Mill Extraction (Deerr) ii) Whole Reduced Extraction (Mittal)		Clarified syrup (after SCS)			
								Sulphured Syrup			
MIXED JUICE					7.	Boiling House Extraction		A-Massecuite			
1. % Cane (Gross)					8.	i) Reduced B.H. Extraction (Deerr) ii) Reduced B.H. Extraction (Rao)		B-Massecuite			
								C_1-Massecuite			
2. % Cane (Net)					9.	Undiluted Juice % Cane		C-Massecuite			
BAGASSE					10.	Undiluted Juice extracted in M.J. Cane		A-Heavy Molasses			
1. % Cane					11.	Undiluted Juice lost in Bagasse % Fibre		B-Heavy Molasses			
2. Pol %					12.	Java Ratio		A-Light Molasses			
3. Moisture %					13.	Clarification Efficiency		C1-Heavy Molasses			
4. Fibre %					14.	F. Molassess Sent out		C-Light Molasses			
FILTER CAKE					i)	On date (Qtls)		B-Magma			
Pol %					ii)	To date (Qtls)		C-Magma			
% Cane								Seed			

FINAL MOLASSES					Hours Lost Due to					Store Consumption				
						On Date		To Date						
1. Brix					Particulars	Hrs	%	Hrs	%	Particulars	On date	%	To date	%
2. Purity					Cane									
3. % Cane					Mechanical Process					Line Stone (Qtls)				
										Lime (Qtls)				
Losses % Cane					Labour Strike					Sulphur (Qtls)				
1. Bagasse					Others Gen. cleaning & Holidays etc.					Other Fuel e.g. Fire wood (Qtls)				
2. Filter Cake										Lubricants (Qtrs) & Grease				
3. F. Molasses					Total					Sugar Production (To date)				
4. Unknown					Total Hrs. Lost %	This Year		Last Year		This Year		Last Year		
5. Total Losses														
Total Losses To date														

GRADE WISE SUGAR PRODUCTION					BOILER FEED / BLOW DOWN WATER ANALYSIS				
Grade	On Date		To Date		Particulars	Boiler Feed Water	Boiler Blow Down Water	Particulars	pH
	Qtls.	%	Qtls.	%					
L-31					Total Hardness pH			Clear Juice	
M-31					Total Dissolved Solids (ppm)			Sulphured Syrup	
S-31					Sugar Traces			Injection Water	
L-30									
M-30					I. Injection Water Temp. Inlet.....oC				
S-30					II. – do – Outlet.....oC				
M-29					**CANE BALANCE**				
S-29					1. At Gate (Qfts.).....				
SS-31					2. At out Centre (Qtls.).....				
BISS/ Ungraded					Total (Qtls.).....				
TOTAL									

MILL STOPPAGES

From	To	Duration	DETAILED REASONS

IMPORTANT BOILING HOUSE STOPPAGES

Sl. No.	Station	Duration	REASONS

REMARKS

Lab. Incharge *Chief Engineer* *Chief Chemist* *General Manager/Executive Director*

COMPARATIVE WEEKLY MANUFACTURING REPORT

Name of the factory.....

Season 200 200

Week Ending on ..... Factory Started Crushing on .....

From .....A.M. of ..... Installed Capacity .....TCD.

To .....A.M. of .....

Sl. No.	PARTICULARS	CURRENT SEASON 200..... 200.....				LAST SEASON 200..... 200.....			
		WEEK		TO DATE		WEEK		TO DATE	
1	2	3		4		5		6	
1.	**Gross Duration (Days)**								
2.	**Cane Crushed (Qlts)**								
3.	**Sugar Production (Qtls)**								
	(i) Sugar Bagged								
	(ii) Net Sugar								
4.	**Sugar Recovery % Cane**								
5.	**Total Hrs. (Gross) Available**								
6.	**Total Hrs. Actual Crushing**								
7.	**Total Hrs. Lost**								
8.	**HOURS LOST DUE TO**	WEEK		TO DATE		WEEK		TO DATE	
	Particulars	Hrs.	%	Hrs.	%	Hrs.	%	Hrs.	%
(A)	Cane Shortage								
(B)	Mechanical								
(C)	Process								
(D)	General Cl. & Holidays								
(E)	Hydel Failure								
(F)	Labour Trouble								
(G)	Grower's Trouble								
(H)	Miscellaneous								
	TOTAL								
9.	**Crushing Rate (Qlts)**								
	(a) On 24 Hrs Including all Stoppages								
	(b) On 24 Hrs. Excluding all stoppages								
	(c) On 22 Hrs. Excluding all stoppages								
10.	**% Capacity Utilisation**								
	(i) On the basis of (a)								
	(ii) On the basis of (b)								
	(ii) On the basis of (c)								
11.	**Cane**								
	(i) Sugar %								
	(ii) Fibre %								
12.	**Imbibition (Maceration)**								
	(i) % Cane								
	(ii) % Fibre								
13.	**Mixed Juice % Cane (Net)**								
14.	**Net Juice % Cane [13-12 (i)]**								
15.	**Bagasse**								
	(i) % Cane								
	(ii) Pol %								
	(iii) Moisture %								
16.	**Filter Cake**								
	(i) % Cane								
	(ii) Pol %								
17.	**Final Molasses**								
	(i) Cane %								
	(ii) Brix								
	(iii) Purity								
	(iv) Sent Out (Qtls)								

1.	2.		3.	4.	5.	6.
18.	**Analysis**					
	(i) Primary Juice	Brix				
		Purity				
	(ii) Mixed Juice	Brix				
		Purity				
	(ii) Clarified Juice	Brix				
		Purity				
19.	**Sugar Balance**					
	(i) Sugar in Cane					
	(ii) Sugar in Mixed Juice					
	(iii) Sugar in Bagasse					
	(iv) Sugar in Filter Cake					
	(v) Sugar in Final Molasses					
	(vi) Sugar in Sugar					
	(vii) Sugar undetermined					
	(viii) **Total Losses**					
20.	**Efficiency Figures**					
	(a) Mill Extraction					
	(b) Reduced Mill Extraction (Derr)					
	(c) Whole Reduced Extraction (Mittal)					
	(d) Boiling House Extraction					
	(e) Reduced B.H. Extraction (Rao)					
	(f) Over all Extraction					
	(g) Reduced Over all Extraction					
	(h) Clarification Efficiency					
21.	**Store Consumption % Cane**					
	(i) Lime Stone					
	(ii) Lime					
	(iii) Sulphur					
	(iv) Firewood					
	(v) Furnace Oil					
	(vi) Lubricants & Grease					
	(vii) Extra Bagasse Consumed % Cane if any					
	(viii) Bagasse Saved % Cane if any					
	(ix) Total Fuel Consumed in terms of Bagasse					

22.	**Grade Wise Sugar Production**								
	ISS GRADE	QTLS	%	QTLS	%	QTLS	%	QTLS	%
	L-31								
	M-31								
	S-31								
	SS-31								
	L-30								
	M-30								
	S-30								
	M-29								
	S-29								
	BISS/Ungraded								
	Total								

23.	**Important Boiling House Stoppages**		
	STATION	DURATION	REASONS

24.	**Reason For Poor Sugar Recovery If Any :**

Lab. Incharge *Chief Engineer* *Chief Chemist* *General Manager/Executive Director*

QUANTITIES

	Run	To-date	Corresponding period last year
Cane			
Sugar in cane			
Mixed Juice			
Brix in Mixed Juice ...			
Sugar in Mixed Juice ...			
Non-Sugar in Mixed Juice ...			
Non-Sugar in Clear Juice ...			
Added Water			
Bagasse			
Fibre in Bagasse			
Sugar in Bagasse ...			
Water in Bagasse ...			
Press Mud			
Sugar in Press Mud ...			
Sugar in Process This Run ...			
Sugar in Process Previous ...			
Molasses Produced ...			
Molasses in Process this Run ...			
Molasses in Process Previous ...			
Brix in Molasses ...			
Sugar in Molasses ...			
Non-Sugars in Molasses ...			
Grade wise sugar production ...			
All Sugars ...			

ANALYSIS TO-DATE

	Brix	Pol	Py	Sucrose Purity	Reducing sugar per 100° Brix	Ash %	pH	Moisture %	Fibre %
CANE									
Primary Juice									
Last Expressed Juice.									
Mixed Juice									
Clear Juice									
Syrup									
Final Molasses									
Bagasse									
Press-Cake									
SUGAR									

TIME ACCOUNT

	RUN		TO-DATE	
	Hrs.	Min.	Hrs.	Min.
Total hours of the Run				
Available hours				
Mills worked Hours				
Hours worked % available				
Total stoppages				
(i) Agricultural				
(ii) Mechanical				
(iii) Chemical				
(iv) Cleaning				
(v) Miscellaneous				

SUGAR BAGGING

	Run	To-date	B.I.S. No.	Run	%	To-date	%
Previous Balance							
Bagged							
Dispatched							
Balance							

MOLASSES ACCOUNT

	RUN	TO-DATE
Previous balance		
Produced		
Sent out		
Balance		

QUANTITIES

CANE	Brix	Pol	Py.	Sucrose Purity	Reducing Sugar per 100° Brix	Ash %	pH	Moisture %	Fibre	CaO/P_2O_5 (mg/l)
Primary Juice										
Last Expressed Juice										
Mixed Juice										
Clear Juice										
Syrup										
Final Molasses										
Bagasse										
Press-Cake										
SUGAR										

CONSUMABLE STORES

	Run	% Cane	To-date	% Cane
Coal / Wood				
Lime				
Sulphur				
Phosphate				
Hydrosulphite				
Filter-Aid				
Caustic Soda				
Washing Soda				
Gunny Bags				
Lubricants				
Biocide				
Viscosity reducer				
Any other material *e.g.* resins, colour precipitant & flocculant etc.				

CONTROL DATA

	Run	To-date	Corresponding period last year
Pol % Cane			
Mixed Juice % cane			
Bagasse % Cane			
Added Water % Cane			
Added Water % Fibre			
Press Cake % Cane			
Molasses % Cane			
Recovery % Cane			
Fibre % Cane			
Mill Extraction			
Boiling House Recovery			
Overall Recovery			
Lost Juice % Fibre			
Reduced Mill Extraction (Deerr) ...			...
Whole Reduced Extraction (Mittal) ...			
Reduced Boiling House Recovery (Gundu Rao)			
Reduced Overall Recovery			

SUGAR ACCOUNT

	Cane = 100		Sugar in Cane = 100		Sugar in mixed Juice = 100	
	Run	To date	Run	To date	Run	To date
Cane						
Bagasse						
Mixed Juice						
Commercial Sugars						
Standard Granulated						
Molasses						
Press Mud						
Undetermined						

CANE SUPPLIES

	Run	%	To-date	%	Varieties	Run	%	To-date	%
Own									
Gate Cane									
Outside									
Total									

FUEL AND BOILER CONTROL

	RUN	TO-DATE
Bagasse Burnt		
Wood and Other Fuel		
Total Fuel in terms of Bagasse of 45% Moisture as standard fuel		
Standard Bagasse used % Cane		
Average Boiler Heating Surface in operation		
Temperature of Furnace		
Temperature of Gases after Boiler or Economiser or Air-per-heater		
Temperature of Feed Water ^{o}C		
Average Live Steam Conditions :–		
(a) Pressure kg per Sq. cm		
(b) Temperature ^{o}C		
(c) Dryness		
Average Exhaust Steam conditions :–		
(a) Pressure		
(b) Temperature		
(c) Dryness		
Total Steam Generated		
Equivalent Evaporation per kg of Standard Bagasse		
Equivalent Evaporation % Cane		
Flue Gas Analysis (CO_2%)		
Draught at Chimney (cm)		

STEAM ACCOUNT

	RUN	TO-DATE
I. Total Steam generated :-		
Steam through Prime Movers		
Direct Steam for Processing		
II. Individual Units :-		
(a) Juice Heaters		
(b) Evaporators		
(c) Pans		
(d) Centrifugal, sulphur furnace and other misc. uses.		

GENERAL REMARK :-

Gen. Manager/Ex. Director ***Lab-in-Charge-Chemist*** ***Chief Engineer*** ***Chief Chemist***

NAME OF THE FACTORY.....

GENERAL

CANE ENGINEERING AND

Season

Coop Day.....

Crushing Capacity.....

(A) Licensed..... TCD. (B) Installed..... TCD.

Hours	No. of Juice Tanks	No. of Imbibition water Tanks	MILL STOPPAGES				Pol % Bagasse	Moisture % Bagasse	Temp. °C Feed Water	pH Feed Water	Pol. % Bagasse	INJECTION WATER			VACCUM IN Cms.	
			From	To	Duration	Reasons						Inlet Temp. °C	Outlet Temp. °C	pH	At Evaporator	Pans
11 AM																
12 NOON																
1 PM																
2 PM																
3 PM																
4 PM																
5 PM																
6 PM																
TOTAL																
7 PM																
8 PM																
9 PM																
10 PM																
11 PM																
12 PM																
1 AM																
2 AM																
TOTAL																
3 AM																
4 AM																
5 AM																
6 AM																
7 AM																
8 AM																
9 AM																
10 AM																
TOTAL																

Cane crushed in Qtls. { To Day _____ / To Date _____ } Recovery { To Day _____ / To Date _____ } Sugar Produced in Qtls. { To Day _____ / To Date _____ }

LOG BOOK

MANUFACTURING

200 - 200

Day From..... 10 am of 200

To ..... 10 am of 200

Live Steam Pressure in Kg./Cm^{2}g	Exhaust Steam Pressure in Kg./Cm^{2}g	MAIN STOPPAGES				Final Molasses Purity	Sugar Produced Qtls.	Final Molasses sent out in Qtls.	Jobs To Be Done	Jobs Done During the Shift	Mills Cleaning Timing	Step taken to ensure regular feeding specially in the night/checking of feeding arrangement at night by department heads.	Remarks	Signature of Shift Engineer/ Shift Chemist
		From	to	Duration Hr. Mt.	Reasons									

Cane Indented in Qtls. .....

Cane crushed in Qtls. .....

Balance at the cane carrier in Qtls. .....

Balance at the centres in Qtls. .....

Cane Manager *Chief Engineer* *Chief Chemist* *General Manager*

CHAPTER – XII

ICUMSA PRESCRIBED METHODS OF ANALYSIS

CHAPTER – XII

ICUMSA PRESCRIBED METHODS OF ANALYSIS

ICUMSA (International Commission for Uniform Methods of Sugar Analysis) is a world wide body which brings together the activities of the National Committees for sugar analysis in more than thirty member countries. Methods are recommended for Tentative approval by ICUMSA in the first instance. Upon meeting all the commission's requirements, methods are accorded Official Status. Methods which are demonstrably useful & have found an established application, or which do not lend themselves to collaborative testing, are given an Accepted status.

Procedures for analysing refined sugars, raw sugars, liquid sugar and other sugar house products have been recommended by ICUMSA. Index of some useful & commonly required analytical procedures is as given below. For details of procedures, Methods Book of ICUMSA may be referred.

GS 1 : RAW SUGAR

1	Polarisation	GS 1/2/3-1
2.	Polarisation without wet lead clarification	GS 1/2/3-2
3.	Reducing Sugars in Cane Raw Sugar by the Lane & Eynon constant volume procedure	GS 1/3/7-3
4.	Reducing Sugars by the Luff School procedure	GS 1-5
5.	Solution colour at pH 7.0	GS 1/3-7
6.	Sulphated ash by single sulphitation	GS 1-10
7.	Conductivity ash	GS 1/3/4/7/8-13
8.	Dextran by modified alcohol Haze method	GS 1-15
9.	Starch : BSES Method	GS 1-16
10.	Starch : SPRI Test	GS 1-17
11.	Fine grain : BSES method	GS 1-20
12.	pH by a direct method	GS 1/2/3/4/7/8-23
13.	Sugar moisture by loss on drying	GS 2/1/3-15
14.	Sulphite by Rosaniline Colorimetric method	GS 2/1/7-33
15.	Solutions colour at pH 7.0 by the MOPS method	GS 9/1/2/3-8

GS 2 : WHITE SUGAR

1	Polarisation	GS 2/3-1
2.	Reducing sugars by the Knight & Allen EDTA method	GS 2/3-5
3.	Reducing sugars by the modified other Tilrimetric method	GS 2-6
4.	Solution colour at pH 7.0	GS 2/3-9
5.	Solution colour	GS 2/3-10
6.	Solution colour at pH 7.0 by MOPS method	GS 9/1/2/3-8
7.	Visual appearance using Braun Schweig colour types	GS 2-11
8.	Reflectance	GS 2-13
9.	Moisture by loss on drying	GS 2/1/3-15
10.	Conductivity ash	GS 2/3-17
11.	Iron by a colorimetric method	GS 2/3/7/8-31
12.	Sulphite by the Rosaniline colorimetric method	GS 2/1/7-33
13.	Sulphite by an enzymatic method	GS 2/3-35
14.	Particle size distribution by sieving	GS 2-37
15.	10-day acid beverage floc test	GS 2/3-40
16.	24 hour acid beverage floc test for beet white sugar	GS 2/3-40
17.	Polarisation of white sugar requiring clarification	GS 1/2/3-1
18.	Polarisation without wet lead clarification	GS 1/2/3-2
19.	pH by a direct method	GS 1/2/3/4/7/8-23
20.	Calcium by EDTA titration	GS 8/2/3/4-9
21.	Anti caking agents in powdered white sugars	GS 3-21
22.	Insoluble matter in white sugar	GS 2/3-19

GS 3 : SPECIALITY SUGARS & REFINED LIQUID PRODUCTS

1.	Reducing Sugars in speciality products by the Lane & Eynon constant volume procedure.	GS 1-3
2.	Reducing Sugars in certain refined syrups by the Lane & Eynon constant volume procedure	GS 4-3
3.	Total reducing sugars in refined syrups after hydrolysis by the Lane & Eynon constant volume procedure	GS 4-7
4.	Total reducing sugars in the refined syrups after hydrolysis by the Luff Schoorl procedure	GS 4-9
5.	Solution colour at pH 7.0 of speciality sugars	GS 1-7
6.	Solution colour at pH 7.0 by the MOPS method	GS 9-8
7.	Moisture in speciality sugars by the Karl Fischer procedure	GS 4-12
8.	Conductivity ash	GS 2-17
9.	Sugar moisture by loss in drying	GS 2-15
10.	Conductivity ash in brown sugar	GS 1-13
11.	Conductivity ash in refined sugar products	GS 2-17
12.	Calcium by EDTA titration	GS 8-9
13.	Total mesophilic bacterial count by membrane filtration method	GS 2-41
14.	Sampling of refined products for microbiological analysis	GS 2-42
15.	Total mesophilic bacterial count by Pour Plate method	GS 2-43
16.	Slime forming bacterial count	GS 2-45
17.	Yeasts & Moulds	GS 2-47
18.	Thermophilic spore forming bacterial	GS 2-49
19.	Polarisation of the sugar component of powdered sugar containing anti-caking agents	GS 3-1
20.	Fructose, glucose & sucrose in cane juices, syrups & molasses by gas chromatography	GS 7/4/3-22

GS 4 : MOLASSES

1.	Apparent sucrose in molasses by a double Polarisation method	GS 4/7-1
2.	Sucrose by GC in molasses, factory products & cane juice	GS 4/7/8/5-2
3.	Fructose, Glucose & Sucrose in cane juices, syrups & molasses & of sucrose in beet molasses by HPIC	GS 7/8/4-24
4.	Reducing Sugars in cane molasses by the Lane & Eynon constant volume procedure	GS 4/3-3
5.	Total reducing sugars in molasses after hydrolysis by the Lane & Eynon constant volume procedure	GS 4/3-7
6.	Total reducing sugars in molasses after hydrolysis by the Luff schoorl procedure	GS 4/3-9
7.	Dry substance & moisture in molasses by vacuum oven drying on sand	GS 4/7-11
8.	Moisture in speciality sugars, molasses, cane raw sugars & syrups by the Karl Fischer Procedure	GS 4/7/3-12
9.	Refractrometric dry substance of molasses	GS 4-13
10.	Sulphated ash in molasses	GS 3/4/7/8-11
11.	Conductivity ash in molasses	GS 1/3/4/7/8/13
12.	Calcium by EDTA titration	GS 8/2/3/4-9
13.	Apparent Dry Substance (^{0}Brix) of molasses using a hydrometer	GS 4-15
14.	Determination of pH	GS 1/2/3/4/7/8-23

GS 5 : SUGAR CANE

1.	Cane Pol, Brix and fibre in cane & bagasse by the wet disintegration method	GS 5/7-1
2.	Sampling of sugarcane by the full width Hatch sampler	GS 5-5
3.	Sampling of sugarcane by Corer method	GS 5-7

GS 7 : CANE SUGAR PROCESSING

1.	Preparation index of cane	GS 7-3
2.	Moisture in cane & bagasse	GS 7-5
3.	Pol of filter cake	GS 7-7
4.	Moisture in filter cake	GS 7-9
5.	Mud solids in juice, mud & filter cake	GS 7-11
6.	Cane fibre in juice, mud & filter cake	GS 7-13
7.	Total & soluble phosphate in cane juice	GS 7-15
8.	Calcium & magnesium in cane juice and syrup by EDTA titration	GS 7-19
9.	Turbidity in clarified cane juice	GS 7-21
10.	Determination of pH	GS 1/2/3/4/7/8-23
11.	Sulphite in cane juice & syrups by Rosaniline colorimetric method	GS 2/1/7-33
12.	Sulphated ash in juice & pan products	GS 3/4/7/8-11
13.	Apparent sucrose by Double Polarisation method	GS 4/7-1
14.	Calcium oxide in lime	GS 7-25
15.	Sucrose - soluble alkali in quick lime	GS 7-27

CHAPTER – XII A

COLOUR BASED TECHNICAL CONTROL IN SUGAR PROCESSING

CHAPTER – XII A

COLOUR BASED TECHNICAL CONTROL IN SUGAR PROCESSING

Courtesy : Dr. (Mrs.) V.S. Keskar

M/s. Maarc Labs Pvt. Ltd., Pune

COLOUR

In the context of sugar industry the word "colour" does not mean the visual appearance of sugar but the amount and intensity of colouring matters or colourants present per unit amount of sugar. A pure sugar crystal is colourless. Commercial white sugar crystals are coloured due to presence of impurities as inclusions within the sugar crystals or as a thin film of molasses on the surface of the crystal. As the exact nature of colouring matters is unknown the relation between visual colour and amount of colouring matters cannot be established nor directly evaluated. International Commission for Uniform Methods of Sugar Analysis (ICUMSA) has, therefore, standardized various methods of colour analysis through which a meaningful relationship between colouring matters and analytical results can be established.

The colour of sugar is measured in solution. Due to physico optical problems of unfiltered solutions ICUMSA has recommended to remove turbidity by filtering the test solution. Colour is specified as ICUMSA units which is the absorbency index of a filtered sugar solution at 420 nm, multiplied by 1000. Absorbancy index (a_s) is defined as A_s / bc where "A_s" is absorbance of sugar solution at 420 nm, "b" is cell length in cm and "c" is concentration in g/mL.

ICUMSA methods for colour analysis: After the Interim ICUMSA meeting held at Atlanta in April 2004,there are four methods for sugar colour analysis. The method for a particular sugar or sugarhouse product is selected according to the scope and application range of the method.

The method numbers, scope and application range of four existing ICUMSA methods of colour analysis are given in the following table:

TABLE 1

Sr. No.	Method No. And Year	Status	Scope	Colour Range
1.	GS 2/3 – 10(2002)	Official	White Sugar	Below 50 IU
2.	GS 2/3 – 9(2002)	Accepted	All crystalline, powdered white sugar, very pure syrups, white sugar, plantation white sugar	Upto 600 IU with no lower limit
3.	GS 1/3 – 7(2002)	Official	Raw sugar, partly refined sugar, brown sugar, juices, syrups.	From 250 IU with no upper limit
4.	GS 9/1/2/3 – 8(2004)	Official	White sugar, plantation white sugar, raw sugar.	Up to 16000IU with no lower limit

* *For detail methods recent edition of ICUMSA method book should be referred.*

Basic principle of colour analysis in all methods is almost same and these methods are validated by conducting a number of International Collaborative studies. Critical points in colour measurement are as follows:

CONCENTRATION OF TEST SOLUTION

The concentration of sugar solution is selected on the basis of amount of colouring matters present in the test product. For low colour sugars higher concentration is required where as for darker products, concentration is reduced. In essence the sugar or sugar product is diluted in such a way that the absorbance reading is obtained in an accuracy range of the spectrophotometer.

CONCENTRATION MEASUREMENT

Concentration of sugar solution is measured by refractometer in terms of RDS (refractometric dry substance) and ICUMSA Table SPS – 4 is referred to get corresponding Concentration(c) in g/mL. For method GS 9/1/2/3 – 8 RDS measurement is not required as c is directly obtained from the aliquot of the sugar taken for analysis.

SPECTROPHOTOMETER

In colour analysis accuracy of spectrophotometer is very important as this analysis does not have any standard graph. Selection of spectrophotometer should be done critically by understanding the accuracy required. ICUMSA has specified spectrophotometer with narrowest practical bandwidth eg. ± 10nm for all methods. However for better accuracy of the results JCP Chen has recommended use of spectrophotometer with minimum ± 4 nm bandwidth.

For method GS 9/1/2/3-8 spectrophotometer requirements are still more stringent i.e. wavelength reproducibility ± 0.5nm and absorbance reproducibility ± 0.003 at 1.0 absorbancy. If ICUMSA requirements of spectrophotometer are not met results are not considered as valid.

CELL LENGTH

Optical cells should be selected depending upon the colour range of the product to be tested. For low coloured sugar higher cell length is used where as higher colour products are analyzed with lower cell length. The solution concentration and cell length are chosen to give an absorbance in the preferred range of spectrophotometer i. e.0.8 to 0.1. For plantation white sugar 5cm cells are appropriate whereas a cell length of 10cm is to be preferred for refined sugar.For high coloured products like raw sugar ,juices,syrups etc 1cm cell is appropriate.

CALCULATIONS

Colour value is calculated using the formula

$$\text{ICUMSA Colour} = \frac{A_S}{bc} \times 1000$$

where A_s - absorbance at 420nm

b - cell length in cm

c - concentration in g/mL

Results are expressed as $IU_{7.0}$ in all methods except GS 2/3-10 where they are expressed only as IU.

Results under 1000 IU are expressed to the nearest 1IU and results over 1000 IU to the nearest 10 IU.

COLOUR BALANCE OF PLANTATION WHITE SUGAR PROCESSING

Colour in cane is made up of many different compounds which can be classified according to their origin in a following manner –

a. From Sugar cane:

   i. Polyphinolic, phenolic and flavonoid colorants which change their colour with pH change.

   ii. Colour precursors like reducing sugars, amino acids and enzymes.

b. Formed in the process:

   i. maillard reaction products, formed by reducing sugars and amino acids.

   ii. Thermal degradation products like melanins and caramels.

   iii. Alkaline degradation products of fructose.

Colour removal and control of colour formation have always been important process factors to plantation white sugar manufacturing. Technologists are becoming increasingly aware of the importance of colour as a quality factor and of colour formation as a quantitative indicator of sucrose loss. Here colour balance study of processing can become important tool in monitoring efficiency and performance of various processing stations.

In nutshell colour balance study can be described as-

To monitor the colour-

a. entering in the process.

b. developed in the process.

c. removed in the process.

d. retained in the sugar crystal.

It is possible to calculate colour balance for each process stage or for the entire process but the prerequisite for such a procedure is that all colour measurements are made at the same wavelength, pH value and dry substance content.

METHODOLOGY

Analysis of all factory intermediates is done by ICUMSA method GS 1/2/3-7. Following steps in the analysis require special attention -

1. **Sample preparation:** Process intermediates are diluted with distilled water taking into consideration colour range, brix and filterability of the product. Following chart can serve as a guideline for preparing dilutions –

TABLE 2

Sr. No.	Factory Intermediate	Final Dilution
1.	Primary Juice, Mixed juice, B-Massecuite, C-Massecuite, A-Heavy, B- Heavy, C – Light, Final Molasses. Oliver filtrate	Brix 2.5 ± 0.5
2.	Sulfited Juice, Clear Juice, Syrup, Sulfited Syrup, A – Light, A-Massecuite, Melt,	Brix 5.0 ± 1.0
3.	B- Sugar, CFW Sugar, CAW Sugar, Dry Seed	Brix 20.0 ± 5.0

2. **pH:** pH of diluted sample is adjusted to 7.00 ± 0.05 with dilute HCl or NaOH before filtration.

3. **Filtration:** filtration of sample can be carried out using syring and plastic holder fitted with membrane filter. Samples of raw juice require pre filtration. Pre-filters are readily available in market.

4. **Wavelength:** The colour of all processing intermediates is to be measured only at 420 nm since the 'colour in solution' of the final product i.e sugar is determined at this wavelength in all 4 ICUMSA methods. In 1990, after a collaborative study using both 420nm and 560nm, ICUMSA concluded that there was no advantage to the use of 560nm compared to 420nm, as the tests showed the 420nm method to be twice as precise. Therefore 420nm is specified by ICUMSA for all colour analyses. Further measurement at 560nm can also lead to misinterpretation because the factor to convert $colour_{560nm}$ to $colour_{420nm}$ is not constant, but varies from factory to factory. Important processing stations and significance of colour balance study at each station are as follows –

    1. **Milling**

    Quality of mixed juice plays an important role as it decides the initial amount of colorants entering in the process. A wide variation in colour of mixed juice is observed (from 8,000 IU to 40,000 IU). The main reasons for this variation are as follows-

    a. **Variety of Sugarcane:** Different cane varieties are grown in India as per agro-climatic conditions. Colour range of juice from these varieties varies

from 17000 to 32000 IU in North India and 7000 to 15000 IU in South India.

b. **Maturity of Cane:** Immature cane contains more coloring matters especially pigments like chlorophyll and anthocyanins. There is gradual decrease in the colour of mixed juice as the season progresses due to maturity of the cane crushed.

c. **Cleanliness of Cane:** In India harvesting of cane is done manually. If cane is not de-trashed and cleaned properly the colour of mixed juice increases. Presence of roots and extraneous matter also adds to the colour.

d. **Binding material:** In manually done harvesting, sugarcane sticks are tied with the help of green leaves. This binding material is crushed along with the cane. Polyphenolics and flavonoids are mainly present in leaves and tops than in the stalk which increase the colour of the mixed juice.

e. **Colour extraction at milling:** During extraction of juice in the milling tandem, coloring matters from cane are also extracted in the juice. These are mainly phenolic compounds and amino acids. Phenolics react with iron from mills forming brown colour product and amino acids react with reducing sugars giving rise to dark colour product in further processing.

2. **Oliver Filtrate**

Though colour values of filtrate are not so high the polyphenol content in it is very high. (about 3,000 ppm). These colour precursors are recycled back through filtrate in mixed juice leading to increasing load on sulfitation and clarification process.

3. **Juice Sulfitation**

This is the first colour removing stage of the process, where most of the natural colorants are precipitated and bleached.. Although the basic phenomenon of colour removal is same in all factories the extent of colour reduction varies widely which can be attributed to -

a. Design of juice sulfitor.

b. Liming - shock liming / pre-liming / simultaneous liming.

c. Quality, quantity and brix of lime.

d. Quality of mixed juice with respect to natural colourants.

e. Temperature of raw juice and reaction time.

f. Temperature and dose of SO_2.

In the process of juice sulfitation maximum colour reduction is required, to get low coloured clear juice. In the factories with optimized juice sulfitation process, upto 50% colour removal from mixed juice can be achieved. In few factories colour removal as low as only 15% is observed which is the main reason behind production of high coloured sugar.

4. Clarification

During clarification process insoluble impurities from juice are settled. However in the clarifier, juice is held at higher temperature for a long time, increasing chances of formation of process derived colorants. Colour increase to the tune of 25% is found in some clarifiers and the probable reasons behind this colour rise could be-

a. High retention time, pH and temperature of juice in clarifier.

b. Presence of bagacillo particles.

c. Iron and reducing sugar content of juice.

d. Improper mud removal from clarifier compartment.

e. Presence of un-reacted lime.

A wide compartment-wise variation in colour is also observed in some clarifiers. This is mainly due to defective design of the clarifier and formation of mud pockets in some compartments.

5. Evaporation

The difference between colour of clarified juice and unsulphited syrup reflects the increase in colour intensity during evaporation process. Due to heat, colour formation takes place in juice in evaporators giving rise to caramalisation, sucrose inversion and melanoidin formation. The nature and amount of colour formation in evaporators is mainly related with iron content of the clear juice. When the evaporation is conducted rapidly with perfect juice circulation and controlled temperature, the colour formation can be maintained at minimum level. Almost nil colour formation during evaporation is observed in some factories, whereas examples of colour rise of even upto 20% are also observed.

6. Syrup Sulfitation

This is a second colour removing stage of the process where maximum colour reduction up to 25 % is observed in very few factories. In most of the factories the colour removal is not consistent because of fluctuating brix and flow rate of syrup as well as irregular and inadequate SO_2 gas generation. Many times the visual appearance of sulfited syrup is golden yellow but this may be due to low pH and not necessarily due to bleaching effect.

7. Crystallization

The colour of A – Massecuite depends on the qualitative and quantitative proportion of intermediate products taking part in A-Massecuite boiling i.e. sulphured syrup, A Light molasses, B and C sugar melts and seed. It is always beneficial to keep the colour of A –Massecuite minimum as a positive correlation between the colour of A Massecuite and colour of sugar is observed.

The difference in colour of B Massecuite and A Heavy gives an idea about increase in colour during B – Massecuite boiling. The average colour increase is about 10 % with minimum colour increase of 2% and maximum of 30 %. The ratio of colour of B Sugar to B Massecuite shows the efficiency of centrifugation and washing of Massecuite. The average ratio was observed in the range of 0.1, the minimum being 0.05 and maximum 0.29.

8. Centrifugation

The aim of a centrifugal machine is to separate pure sugar crystals from an impure Massecuite. Regular analysis of colour of sugar and massecuite is helpful to evaluate performance of centrifugal machines as well as for optimize their working. The colour transfer factor (CTF) compares colour of sugar with that of mother liquor i.e. massecuite. For A – centrifugals CTF below 0.01 is considered to be ideal for getting low coloured sugar. Even though same A – Massecuite is centrifuged in all machines many times some centrifugals drop sugar with very high colour. Mechanical faults like continuous leakage of molasses from pug mill and chocking of inner screens were found to be major reasons behind their poor performance. Optimization of centrifugal working with combination of various parameters like quantity and temperature of wash water, steam, timing and speed of the machine and Massecuite quality is very much useful to improve performance of this station.

The average ratio of colour of B – sugar to B – massecuite is observed in the range of 0.1, the minimum being 0.05 and maximum 0.3. The ratio of colour of CFW sugar to C – massecuite and CAW sugar to CFW sugar indicates efficiency of purging by continuous centrifugals.

9. Grass Hoppers

In some factories even though performance of centrifugal machines is satisfactory CTF is very high and colour of sugar increases up to 45% during hopper passage. The reason behind this increase was formation of layer of high coloured molasses tricked from centrifugal machine on surface of hoppers.

Thus production of low coloured A – Massecuite is not sufficient. If working at centrifugal machines and hoppers is unsatisfactory, in-spite of excellent performance in earlier processing stations, there is tremendous increase in the colour of sugar at the last stages.

TABLE 3

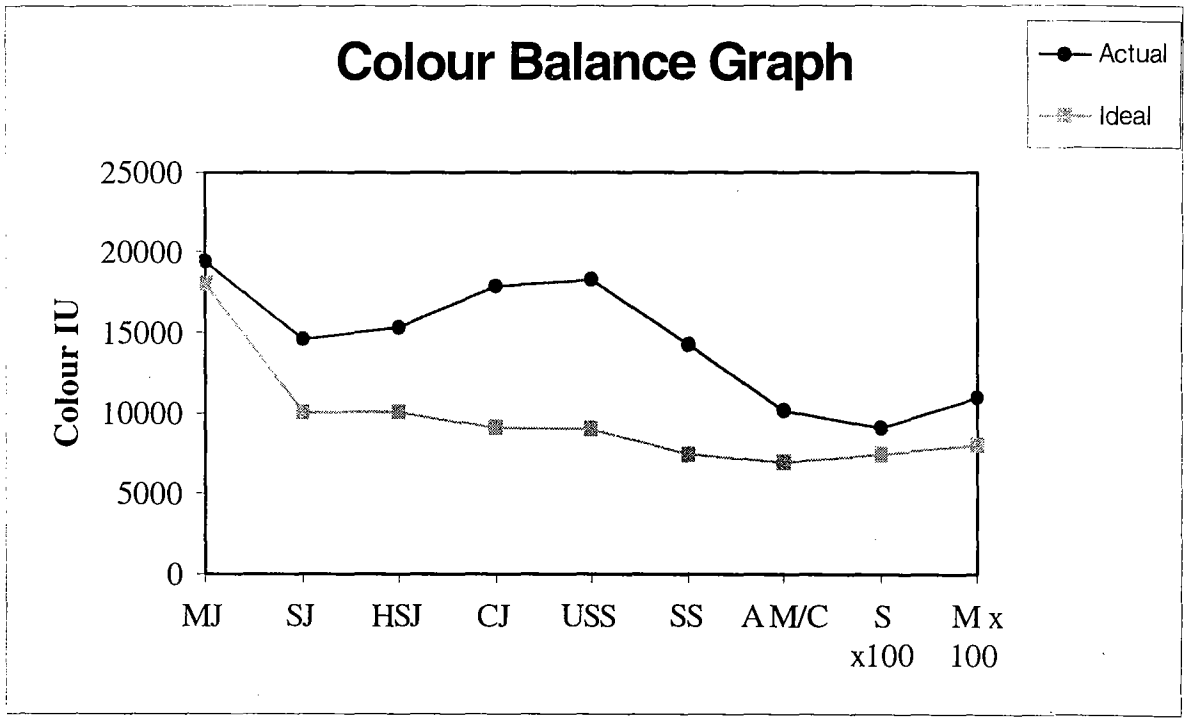
Typical colour range of processing intermediates in Indian sugar mills

Sr. No.	Factory Intermediates	Colour range
1.	Mixed Juice	9000 to 31,000 IU
2.	Oliver filtrate	12000 to 32000 IU
3.	Sulfured juice	8000 to 17000 IU
4.	Clear juice	8000 to 20,000 IU
5.	Un sulfured syrup	8000 to 22,000 IU
6.	Sulfured syrup	6000 to 18,000 IU
7.	A-massecuite	6000 to 19,000 IU
8.	A-heavy	16,000 to 26,000 IU
9.	A-light	4000 to 14,000 IU
10.	B-massecuite	18,000 to 34,000 IU
11.	B sugar	800 to 3000 IU
12.	B-heavy	25,000 to 60,000 IU
13.	CFW Sugar	8000 to 27,000 IU
14.	CAW Sugar	600 to 4,500 IU
15.	Dry Seed	250 to 700 IU
16.	C-massecuite	25,000 to 75,000 IU
17.	C-Light	25,000 to 65,000 IU
18.	Final molasses	30,000 to 80,000 IU

COLOUR BALANCE GRAPH

After calculating colour values for different process intermediates a colour balance graph of the process can be plotted. Colour values of Mixed juice, Sulphited juice, Heated sulphited juice, Clear juice, Syrup, Sulphited syrup and A-massecuite are plotted on the Y axis of the graph against their corresponding intermediate. As sugar colour value is very low as compared to other intermediates it is multiplied by 100 to fit it in the graph.Ideal colour balance graph is given in Fig. I and any deviation from this graph gives indication about the problems at particular processing station and corrective action can be taken accordingly.

Fig. 1



CONCLUSION

Thus colour balance study of plantation white sugar processing gives clear idea about the stations responsible for colour increase as well as efficiency of colour removing stations. Based on the data of this study various measures can be taken to produce sugar with very low colour.

REFERENCE TABLES

REFERENCE TABLES

Table No.

I True density, apparent density and weight per unit volume of water at temperatures 0° to 100°C.

II Density (in grams per litre) of water at different temperatures for calibration of apparatus.

III-A Degree Brix and Specific Gravity of sugar solutions at 20°C.

III-B Brix and Specific Gravity of sugar solutions at 27.5°/27.5°C

IV-A Correction of readings of Brix Scale for variations in temperatures from 20°C.

IV-B Correction of readings of Brix Scale for variationsin temperature from 27.5°C.

V-A Schmitz's table for Pol for use in Horne's Dry Lead method (Temperature 20°C.)

V-B Schmitz's table for Pol for use in Horne's Dry Lead method (Temperature 27.5°C).

VI Specific Gravities of common acids and alkalies (in aqueous solutions).

VII-A Invert Sugar table for 10 ml of Fehling's solution.

VII-B Invert Sugar table for 25 ml of Fehling's solution.

VIII-A Head value, in calories per kilogram, of bagasse burned (Stack temperature 260°C).

VIII-B GCV and NCV of bagasse for different values of sugar and moisture percent bagasse.

IX Weight of solids (Brix) in Kilograms per litre of sugar solution at 20°C ad 27.5°C.

X Amount of CaO in milk of lime of various densities at 15°C (From Blatner's Table).

XI-A Thermodynamic properties of dry saturated steam in metric units.

XI-B Thermodynamic properties of dry saturated steam in SI units.

XII Total heat of superheated steam in metric units.

XIII Value of $\frac{J - M}{100 - M}$ for J of 40–90 and M of 24–40 purities.

XIV Value of $\frac{100 - J}{J - M}$ x 1.2 for J of 40–90 and M of 24–40 puirities

XV Crystal content of massecuites.

XVI Mensuration of surfaces and solids.

XVII Units of Measurement :

XVII-A S. I. units

XVII-B Prefix symbols and multiplication factors

XVII-C Conversion tables

XVIII Table of Contants

XIX International Atomic Weights.

XX Volume of sucrose solutions at different temperatures.

XXI Increase in volume when sucrose is dissolved in water.

XXII Solubility of sucrose in aqueous alcohol.

XXIII Solubility of pure sucrose in water calculated for unit increments of temp.

XXIV Boiling point elevation for cane products.

XXIV-A Boiling point of water under vacuum.

XXV Specific gravity & brix of milk of lime at 27.5°C

XXVI Solubility of lime in sugar solutions at 25°C

XXVII Solubility of certain salts in water in the presence of sucrose

XXVIII Solubility of invert sugar

XXIX Most soluble mixtures of sucrose and invert sugar

XXX Cellulose Papers – Whatman

APPENDICES

Appendix

A Devices for continuous sampling of First expressed juice and Mixed juice.

B Preparation of Standard solutions.

C Specifications for and methods of standardisation of Brix hydrometers, Saccharimeters and Pol tubes.

D Method of preparation of Seed Slurry.

E Calculation of Brix free cane water percent fibre (BFCW % fibre).

F Indirect method of calculating cane weight

Table I

True Density, Apparent Density and Weight per Unit Volume of Water at Temperature 0 to 100°C (Condensed and recalculated by E. E. Coll, 1961)

Temp., Degrees C.	True Density	Apparent Density kg/liter	Weight per Cubic Foot, lb. (in air)	Weight per Gallon, lb. (in air)	Temp., Degrees C.	True Density	Apparent Density kg/liter	Weight per Cubic Foot, lb. (in air)	Weight per Gallon, lb. (in air)
0	00.99987	0.99881	62.354	8.3355	51	.98762	.98656	.589	8.2333
1	.99993	.99887	.358	.3360	52	.98716	.98010	.560	.2294
2	.99997	.99893	.360	.3363	53	.98669	.98563	.531	.2255
3	.99999	.99803	.361	.3365	54	.98621	.98515	.501	.2215
4	1.00000	.90894	.362	.3366	55	.98573	.98467	.471	.2175
5	0.99999	.99893	.361	.3365	56	.98524	.98418	.441	.2134
6	.99997	.99891	.360	.3363	57	.98475	.98369	.410	.2093
7	.99993	.99887	.358	.3360	58	.08425	.98319	.379	.2052
8	.99988	.99882	.355	.3356	59	.98375	.98269	.348	.2010
9	.99981	.99875	.350	.3350	60	.98324	.98218	.316	.1967
10	.99973	.99867	.345	.3343	61	.98272	.98166	.284	.1924
11	.99963	.99857	.339	.3335	62	.98220	.98114	.251	.1880
12	.99952	.99846	.332	.3326	63	.98061	.28061	.218	.1836
13	.99940	.99834	.324	.3316	64	.98113	.98007	.184	.1791
14	.99927	.99821	.316	.3305	65	.98059	.97953	.150	.1746
15	.99913	.99807	.308	.3293	66	.98005	.97899	.116	.1701
16	.99897	.99791	.298	.3280	67	.97950	.97844	.082	.1655
17	.99880	.99774	.287	.3266	68	.97894	.97788	.047	.1609
18	.99862	.99756	.276	.3251	69	.97838	.97732	.012	.1562
19	.99843	.99737	.264	.3235	70	.97781	.97675	60.977	.1514
20	.99823	.99717	.252	.3218	71	.97723	.97617	.941	.1466
21	.99802	.99696	.239	.3200	72	.97665	.97559	.905	.1418
22	.99780	.99674	.225	.3182	73	.97607	.97501	.868	.1369
23	.99756	.99650	.210	.3162	74	.97548	.97442	.831	.1320
24	.99732	.99626	.195	.3142	75	.97489	.97383	.794	.1270
25	.99707	.99601	.179	.3121	76	.97429	.97323	.757	.1220
26	.99681	.99575	.163	.3099	77	.97368	.97262	.719	.1169
27	.99654	.99548	.146	.3077	78	.97307	.97200	.681	.1118
28	.99626	.99520	.129	.3054	79	.97245	.97138	.642	.1066
29	.99597	.99491	.111	.3030	80	.97183	.97076	.603	.1014
30	.99567	.99461	.092	.3005	81	.97120	.97013	.564	.0962
31	.99536	.99430	.073	.2970	82	.97057	.96950	.525	.0909
32	.99505	.99399	.053	.2953	83	.96994	.96887	.485	.0856
33	.99473	.99367	.033	.2926	84	.96930	.96823	.445	.0803
34	.99440	.99334	.012	.2898	85	.96865	.96768	.405	.0749
35	.99406	.99300	61.991	.2870	86	.96800	.96693	.364	.0695
36	.99371	.99265	.969	.2841	87	.96734	.96627	.323	.0640
37	.99335	.99229	.947	.2811	88	.96668	.96561	.281	.0585
38	.99299	.99193	.924	.2781	89	.96601	.96494	.239	.0529
39	.99262	.99156	.901	.2750	90	.96534	.96427	.197	.0473
40	.99224	.99118	.878	.2719	91	.96467	.96360	.155	.0417
41	.99186	.99080	.854	.2687	92	.96399	.96202	.113	.0360
42	.99147	.99041	.830	.2654	93	.96330	.96223	.070	.0303
43	.99107	.99001	.805	.2621	94	.96201	.96154	.027	.0245
44	.99066	.98960	.779	.2587	95	.96192	.96085	59.984	.0187
45	.99024	.98918	.753	.2552	96	.96122	.96015	.940	.0129
46	.98982	.98876	.727	.2516	97	.96051	.95944	.896	.0070
47	.98939	.98833	.700	.2480	98	.95980	.95873	.852	.0011
48	.98896	.98790	.673	.2444	99	.95909	.95802	.808	7.9951
49	.98852	.98746	.645	.2408	100	.95838	.95731	.763	0.9891
50	.98807	.98701	.617	.2371					

Note : *Column 2 is true density of water at temperature shown in column 1. Wt in vacuo of 1 ml @ 20 C/Wt of 1 ml @ 4C=1000 g. From M. Thiessen. Wiss Abf. Physik. Tech. Reichsanstalt 1904 Column 3, apparent density same as column 2 but weight in air kg/liter or gm[m.*

Columns 4 and 5 column 3 times unit weight in air at 4 C. (Weight in air calculated from wts in vacuo 62.4282 lb. per cubic ft. 8.34544 lb. per/gal. One cubic foot – 7.48052 gal.

Table II

Density (In Grams Per litre) of water at Different Temperatures* for Calibration of Apparatus.

Flask of soda glass, coefficient of cubical expansion, 0.000025/°C.

Temp. (°C.)	Weight (g.)	Volume of 1 g. of Water (ml.)	Temp. (°C.)	Weight (g.)	Volume of 1 g. of Water (ml.)
10	998.39	1.0016	23	996.60	1.0034
11	998.32	1.0017	24	996.38	1.0036
12	998.23	1.0018	25	996.17	1.0038[5]
13	998.14	1.0018[5]	26	995.93	1.0041
14	998.04	1.0019	27	995.69	1.0043
15	997.93	1.0021	28	995.44	1.0046
16	997.80	1.0022	29	995.18	1.0048
17	997.66	1.0023	30	994.91	1.0051
18	997.51	1.0025	31	994.64	1.0054
19	997.35	1.0026	32	994.35	1.0057
20	997.18	1.0028	33	994.06	1.0060
21	997.00	1.0030	34	993.75	1.0063
22	996.80	1.0032	35	993.45	1.0066

Flask of borosillicate glass, coefficient of cubical expansion, 0.000010/°C.

Temp. (°C.)	Weight (g.)	Volume of 1 g. of Water (ml.)	Temp. (°C.)	Weight (g.)	Volume of 1 g. of water (ml.)
15	998.00	1.0020	24	996.33	1.0037
16	997.86	1.0021	25	996.09	1.0039
17	997.71	1.0023	26	995.85	1.0042
18	997.54	1.0025	27	995.49	1.0045
19	997.37	1.0026	28	995.32	1.0047
20	997.18	1.0028	29	995.05	1.0050
21	996.98	1.0030	30	994.76	1.0053
22	996.78	1.0032	31	994.47	1.0056
23	996.56	1.0034[5]	32	994.17	1.0059

Note : *For the calibration of flasks of capacity other than 1 litre, the corresponding multiple or sub-multiple of the above values is taken.*

* *The above figures refer to the apparent weight in grams in air against brass weights, density 8.4 g/ml. The modern basis for density of weights of 8.0 g./ml. will result in a difference of weights of 7.1 parts per million this will obviously not affect the table to the significant figures quoted.*

Taken from Vogel : "Quantitative Inorganic Analysis" 1962 page 195.

Table III-A

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
0.0	0.99823	1.00000	.2	1.01072	1.01251
.1	0.99862	1.00039	.3	1.01112	1.01290
.2	0.99901	1.00078	.4	1.01151	1.01330
.3	0.99940	1.00117			
.4	0.99979	1.00155	3.5	1.01190	1.01369
			.6	1.01230	1.01409
0.5	1.00017	1.00194	.7	1.01269	1.01448
.6	1.00056	1.00233	8.	1.01309	1.01488
.7	1.00095	1.00272	.9	1.01348	1.01528
.8	1.00134	1.00311			
.9	1.00173	1.00350	4.0	1.01388	1.01567
			.1	1.01428	1.01607
1.0	1.00212	1.00389	.2	1.01467	1.01647
.1	1.00251	1.00428	.3	.101507	1.01687
.2	1.00290	1.00467	.4	1.01547	1.01726
.3	1.00329	1.00545	4.5	1.01586	1.01766
			.6	1.01626	1.01806
1.5	1.00406	1.00584	.7	1.01666	1.01846
.6	1.00445	1.00623	.8	1.01706	1.01886
.7	1.00484	1.00662	.9	1.01746	1.01926
.8	1.00523	1.00701			
.9	1.00562	1.00740	5.0	1.01785	1.01965
			.1	1.01825	1.02005
2.0	1.00602	1.00779	.2	1.01865	1.02045
.1	1.00641	1.00818	.3	1.01905	1.02085
.2	1.00680	1.00853	.4	1.01945	1.02125
.3	1.00719	1.00897			
.4	1.00758	1.00936	5.5	1.01985	1.02165
			.6	1.02025	1.02206
2.5	1.00797	1.00976	.7	1.02065	1.02246
.6	1.00836	1.01015	.8	1.02105	1.02286
.7	1.00876	1.01054	.9	1.02145	1.02321
.8	1.00915	1.01093			
.9	1.00954	1.01133	6.0	1.02186	1.02366
			.1	1.02226	1.02407
3.0	1.00993	1.01172	.2	1.02266	1.02447
.1	1.01033	1.01211	.3	1.02306	1.02487

*Taken from 'Sugar Analysis', Icumsa methods (Schneider) 1979 P. 242-252.

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
.4	1.02346	1.02527	.6	1.03649	1.03833
			.7	1.03691	1.03874
6.5	1.02387	1.02568	.8	1.03732	1.03915
.6	1.02427	1.02608	.9	1.03773	1.03957
.7	1.02467	1.02648			
.8	1.02508	1.02689	10.0	1.03814	1.03998
.9	1.02548	1.02729	.1	1.03856	1.04039
			.2	1.03897	1.04081
7.0	1.02588	1.02770	.3	1.03938	1.04122
.1	1.02629	1.02810	.4	1.03980	1.04164
.2	1.02669	1.02851			
.3	1.02710	1.02892	10.5	1.04021	1.04205
.4	1.02750	1.02932	.6	1.04063	1.04247
			.7	1.04104	1.04288
7.5	1.02791	1.02973	.8	1.04146	1.04330
.6	1.02832	1.03013	.9	1.04187	1.04371
.7	1.02872	1.03054			
.8	1.02913	1.03095	11.0	1.04229	1.04413
.9	1.02954	1.03136	.1	1.04270	1.04455
			.2	1.04312	1.04497
8.0	1.02994	1.03176	.3	1.04354	1.04538
.1	1.03035	1.03217	.4	1.04395	1.04580
.2	1.03076	1.03258			
.3	1.03116	1.03299	11.5	1.04437	1.04622
.4	1.03157	1.03340	.6	1.04479	1.04664
			.7	1.04521	1.04706
8.5	1.03198	1.03381	.8	1.04562	1.04747
.6	1.03239	1.03422	.9	1.04604	1.04789
.7	1.03280	1.03463			
.8	1.03321	1.03504	12.0	1.04646	1.04831
.9	1.03362	1.03545	.1	1.04688	1.04873
9.0	1.03403	1.03586	.2	1.04730	1.04915
.1	1.03444	1.03627	.3	1.04772	1.04957
.2	1.03485	1.03668	.4	1.04814	1.04299
.3	1.03526	1.03709			
.4	1.03567	1.03750	12.5	1.04856	1.05041
			.6	1.04898	1.05084
9.5	1.03608	1.03792	.7	1.04940	1.05126

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
.8	1.04982	1.05168	16.0	1.06346	1.06534
.9	1.05024	1.05210	.1	1.06389	1.06577
			.2	1.06432	1.06621
13.0	1.05066	1.05252	.3	1.06476	1.06664
.1	1.05109	1.05295	.4	1.06519	1.06707
.2	1.05151	1.05337			
.3	1.05193	1.05379	16.5	1.06562	1.06751
.4	1.05236	1.05422	.6	1.06605	1.06794
			.7	1.06649	1.06837
13.5	1.05278	1.05464	.8	1.06692	1.06881
.6	1.05320	1.05506	.9	1.06736	1.06924
.7	1.05363	1.05549			
.8	1.05405	1.05591	17.0	1.06779	1.06968
.9	1.05448	1.05634	.1	1.06822	1.07011
			.2	1.06866	1.07055
14.0	1.05490	1.05677	.3	1.06909	1.07098
.1	1.05532	1.05719	.4	1.06953	1.07142
.2	1.05575	1.05762			
.3	1.05618	1.05804	17.5	1.06996	1.07186
.4	1.05660	1.05847	.6	1.07040	1.07229
			.7	1.07084	1.07273
14.5	1.05703	1.05890	.8	1.07127	1.07317
.6	1.05746	1.05933	.9	1.07171	1.07361
.7	1.05788	1.05975			
.8	1.05831	1.06018	18.0	1.07215	1.07404
.9	1.05874	1.06061	.1	1.07258	1.07448
			.2	1.07302	1.07492
15.0	1.05916	1.06104	.3	1.07346	1.07536
.1	1.05959	1.06147	.4	1.07390	1.07580
.2	1.06002	1.06190			
.3	1.06045	1.06233	18.5	1.07434	1.07624
.4	1.06088	1.06276	.6	1.07478	1.07668
			.7	1.07522	1.07712
15.5	1.06131	1.06319	.8	1.07566	1.07756
.6	1.06174	1.06362	.9	1.07610	1.07800
.7	1.06217	1.06405			
.8	1.06260	1.06448	19.0	1.07654	1.07844
.9	1.06303	1.06491	.1	1.07698	1.07888

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
.2	1.07742	1.07932	22.5	1.09216	1.09409
.3	1.07786	1.07977	.6	1.09261	1.09454
.4	1.07830	1.08021	.7	1.09306	1.09499
			.8	1.09351	1.09545
19.5	1.07874	1.08065	.9	1.09397	1.09590
.6	1.07919	1.08110			
.7	1.07963	1.08154	23.0	1.09442	1.09636
.8	1.08007	1.08198	.1	1.09487	1.09381
.9	1.08052	1.08248	.2	1.09533	1.09727
			.3	1.09578	1.09772
20.0	1.08096	1.08287	.4	1.09624	1.09818
.1	1.08140	10.8332			
.2	1.08185	1.08376	23.5	1.09669	1.09863
.3	1.08229	1.08421	.6	1.09715	1.09909
.4	1.08274	1.08465	.7	1.09760	1.09954
			.8	1.09806	1.10000
20.5	1.08318	1.08510	.9	1.09851	1.10046
.6	1.08363	1.08554			
.7	1.08407	1.08599	24.0	1.09897	1.10092
.8	1.08452	1.08644	.1	1.09943	1.10137
.9	1.08497	1.08689	.2	1.09989	1.10183
			.3	1.10034	1.10229
21.0	1.08541	1.08733	.4	1.10080	1.10275
.1	1.08586	1.08778			
.2	1.08631	1.08823	24.5	1.10126	1.10321
.3	1.08676	1.08868	.6	1.10172	1.10367
.4	1.08720	1.08913	.7	1.10218	1.10413
			.8	1.10264	1.10459
21.5	1.08765	1.08958	.9	1.10310	1.10505
.6	1.08810	1.09003			
.7	1.08855	1.09048	25.0	1.10356	1.10551
.8	1.08900	1.09093	.1	1.10402	1.10597
.9	1.08945	1.09138	.2	1.10448	1.10643
			.3	1.10494	1.10689
22.0	1.08990	1.09183	.4	1.10540	1.10736
.1	1.09035	1.09228			
.2	1.09080	1.09273	25.5	1.10586	1.10782
.3	1.09125	1.09318	.6	1.10632	1.10828
.4	1.09170	1.09364	.7	1.10679	1.10874

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
.8	1.10725	1.10921	29.0	1.12223	1.12422
.9	1.10771	1.10967	.1	1.12270	1.12469
			.2	1.12318	1.12517
26.0	1.10818	1.11014	.3	1.12365	1.12564
.1	1.10864	1.11060	.4	1.12413	1.12612
.2	1.10910	1.11106			
.3	1.10957	1.11153	29.5	1.12460	1.12659
.4	1.11003	1.11200	.6	1.12508	1.12707
			.7	1.12556	1.12755
26.5	1.11050	1.11246	.8	1.12603	1.12802
.6	1.11096	1.11293	.9	1.12651	1.12850
.7	1.11143	1.11339			
.8	1.11190	1.11386	30.0	1.12698	1.12898
.9	1.11236	1.11433	.1	1.12746	1.12946
			.2	1.12794	1.12993
27.0	1.11283	1.11480	.3	1.12842	1.13041
.1	1.11330	1.11526	.4	1.12890	1.13089
.2	1.11376	1.11573			
.3	1.11423	1.11620	30.5	1.12937	1.13137
.4	1.11470	1.11667	.6	1.12985	1.13185
			.7	1.13033	1.13233
27.5	1.11517	1.11714	.8	1.13081	1.13281
.6	1.11564	1.11761	.9	1.13129	1.13329
.7	1.11610	1.11808			
.8	1.11657	1.11855	31.0	1.13177	1.13378
.9	1.11704	1.11902	.1	1.13225	1.13426
			.2	1.13274	1.13474
28.0	1.11751	1.11949	.3	1.13322	1.13522
.1	1.11798	1.11996	.4	1.13370	1.13570
.2	1.11845	1.12043			
.3	1.11892	1.12090	31.5	1.13418	1.13619
.4	1.11940	1.12138	.6	1.13466	1.13667
			.7	1.13515	1.13715
28.5	1.11987	1.12185	.8	1.13563	1.13764
.6	1.12034	1.12232	.9	1.13611	1.13812
.7	1.12081	1.12280			
.8	1.12128	1.12327	32.0	1.13660	1.13861
.9	1.12176	1.12374	.1	1.13708	1.13909

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
.2	1.13756	1.13958	35.5	1.15375	1.15579
.3	1.13805	1.14006	.6	1.15425	1.15629
.4	1.13853	1.14053	1.14055	.7	1.15475
			.8	1.15524	1.15729
32.5	1.13902	1.14103	.9	1.15574	1.15778
.6	1.13951	1.14152			
.7	1.13999	1.14201	36.0	1.15624	1.15828
.8	1.14048	1.14250	.1	1.15674	1.15878
.9	1.14097	1.14298	.2	1.15724	1.15928
			.3	1.15773	1.15978
33.0	1.14145	1.14347	.4	1.15823	1.16028
.1	1.14194	1.14396			
.2	1.14243	1.14445	36.5	1.15873	1.16078
.3	1.14292	1.14494	.6	1.15923	1.16128
.4	1.14340	1.14543	.7	1.15973	1.16178
			.8	1.16023	1.16228
33.5	1.14389	1.14592	.9	1.16073	1.16279
.6	1.14438	1.14641			
.7	1.14487	1.14690	37.0	1.16124	1.16329
.8	1.14536	1.14739	.1	1.16174	1.16379
.9	1.14585	1.14788	.2	1.16224	1.16430
			.3	1.16274	1.16480
34.0	1.14634	1.14837	.4	1.16324	1.16530
.1	1.14684	1.14886			
.2	1.14733	1.14936	37.5	1.16375	1.16581
.3	1.14782	1.14985	.6	1.16425	1.16631
.4	1.14831	1.15034	.7	1.16476	1.6682
.8	1.16526	1.16732			
34.5	1.14880	1.15084	.9	1.16576	1.16783
.6	1.14930	1.15133			
.7	1.14979	1.15183	38.0	1.16627	1.16833
.8	1.15029	1.15232	.1	1.16678	1.16884
.9	1.15078	1.15282	.2	1.16728	1.16934
			.3	1.16779	1.16985
35.0	1.15128	1.15331	.4	1.16820	1.17036
.1	1.15177	1.15381			
.2	1.15226	1.15430	38.5	1.16880	1.17087
.3	1.15276	1.15480	.6	1.16931	1.17138
.4	1.15326	1.15530	.7	1.16982	1.17188

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
.8	1.17032	1.17239	42.0	1.18677	1.18887
.9	1.17083	1.17290	.1	1.18729	1.18939
			.2	1.18781	1.18992
39.0	1.17134	1.17341	.3	1.18834	1.19044
.1	1.17185	1.17392	.4	1.18886	1.19096
.2	1.17236	1.17443			
.3	1.17287	1.17494	42.5	1.18938	1.19148
.4	1.17338	1.17545	.6	1.18990	1.19201
			.7	1.19042	1.19253
39.5	1.17389	1.17596	.8	1.19095	1.19305
.6	1.17440	1.17648	.9	1.19147	1.19358
.7	1.17491	1.17699			
.8	1.17542	1.17750	43.0	1.19199	1.19410
.9	1.17594	1.17802	.1	1.19252	1.19463
			.2	1.19304	1.19515
40.0	1.17645	1.17853	.3	1.19356	1.19568
.1	1.17696	1.17904	.4	1.19409	1.19620
.2	1.17747	1.17956	43.5	1.19462	1.19673
.3	1.17799	1.18007	.6	1.19514	1.19726
.4	1.17850	1.18058	.7	1.19567	1.19778
			.8	1.19619	1.19831
40.5	1.17901	1.18110	.9	1.19672	1.19884
.6	1.17953	1.18162			
.7	1.18004	1.18213	44.0	1.19725	1.19936
.8	1.18056	1.18265	.1	1.19778	1.19989
.9	1.18108	1.18316	.2	1.19830	1.20042
			.3	1.19883	1.20095
41.0	1.18159	1.18368	.4	1.19936	1.20148
.1	1.18211	1.18420			
.2	1.18262	1.18472	44.5	1.19989	1.20201
.3	1.18314	1.18524	.6	1.20042	1.20254
.4	1.18366	1.18575	.7	1.20095	1.20307
			.8	1.20148	1.20307
41.5	1.18418	1.18627	.9	1.20201	1.20414
.6	1.18470	1.18679			
.7	1.18522	1.18731	45.0	1.20254	1.20467
.8	1.18573	1.18783	.1	1.20307	1.20520
.9	1.18625	1.18835	.2	1.20360	1.20573

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20°C.

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C
.3	1.20414	1.20627	48.5	1.22136	1.22352
.4	1.20467	1.20680	.6	1.22190	1.22406
			.7	1.22245	1.22461
45.5	1.20520	1.20733	.8	1.22300	1.22516
.6	1.20573	1.20787	.9	1.22354	1.22570
.7	1.20627	1.20840			
.8	1.20680	1.20894	49.0	1.22409	1.22625
.9	1.20734	1.20947	.1	1.22463	1.22680
			.2	1.22518	1.22735
46.0	1.20787	1.21001	.3	1.22573	1.22789
.1	1.20840	1.21054	.4	1.22627	1.22844
.2	1.20894	1.21108			
.3	1.20948	1.21162	49.5	1.22682	1.22899
.4	1.21001	1.21215	.6	1.22737	1.22954
			.7	1.22792	1.23009
46.5	1.21055	1.21269	.8	1.22847	1.23064
.6	1.21109	1.21323	.9	1.22902	1.23119
.7	1.21162	1.21377			
.8	1.21216	1.21431	50.0	1.22957	1.23174
.9	1.21270	1.21484	.1	1.23012	1.23229
			.2	1.23067	1.23284
47.0	1.21324	1.21538	.3	1.23122	1.23340
.1	1.21378	1.21592	.4	1.23177	1.23395
.2	1.21432	1.21646			
.3	1.21486	1.21700	50.5	1.23232	1.23450
.4	1.21540	1.21755	.6	1.12287	1.23506
			.7	1.23343	1.23561
47.5	1.21594	1.21809	.8	1.23398	1.23616
.6	1.21648	1.21863	.9	1.23453	1.23672
.7	1.21702	1.21917			
.8	1.21756	1.21971	51.0	1.23508	1.23727
.9	1.21810	1.22026	.1	1.23564	1.23782
			.2	1.23619	1.23838
48.0	1.21864	1.22080	.3	1.23675	1.23894
.1	1.21918	1.22134	.4	1.23730	1.23949
.2	1.21973	1.22189	51.5	1.23786	1.24005
.3	1.22027	1.22243	.6	1.23841	1.24060
.4	1.22082	1.22298	.7	1.23897	1.24116

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
.8	1.23953	1.24172	55.0	1.25754	1.25976
.9	1.24008	1.24228	.1	1.25810	1.26003
			.2	1.25867	1.26090
52.0	1.24064	1.24284	.3	1.25924	1.26147
.1	1.24120	1.24339	.4	1.25982	1.26204
.2	1.24176	1.24395			
.3	1.24232	1.24451	55,5	1.26039	1.26261
.4	1.24287	1.24507	.6	1.26096	1.26319
			.7	1.26153	1.26376
52.5	1.24343	1.24563	.8	1.26210	1.26433
.6	1.24399	1.24619	.9	1.26267	1.26490
.7	1.24455	1.24675			
.8	1.24511	1.24731	56.0	1.26324	1.26548
.9	1.24567	1.24788	.1	1.26382	1.26605
			.2	1.26439	1.26663
53.0	1.24623	1.24844	.3	1.26496	1.26720
.1	1.24680	1.24900	.4	1.26554	1.26778
.2	1.24736	1.24956			
.3	1.24792	1.25013	56.5	1.26611	1.26835
.4	1.24848	1.25069	.6	1.26669	1.26893
			.7	1.26726	1.26950
53.5	1.24905	1.25126	.8	1.26784	1.27008
.6	1.24961	1.25182	.9	1.26841	1.27066
.7	1.25017	1.25238			
.8	1.25074	1.25295	57.0	1.26899	1.27123
.9	1.25130	1.25351	.1	1.26956	1.26181
			.2	1.27014	1.27239
54.0	1.25187	1.25408	.3	1.27072	1.27297
.1	1.25243	1.25465	.4	1.27130	1.27355
.2	1.25300	1.25521			
.3	1.25356	1.25578	57.5	1.27188	1.27413
.4	1.25413	1.25635	.6	1.27246	1.27417
			.7	1.27304	1.27529
54.5	1.25470	1.25692	.8	1.27361	1.27587
.6	1.25526	1.25748	.9	1.27419	1.27645
.7	1.25583	1.25805			
.8	1.25640	1.25862	58.0	1.27477	1.27703
.9	1.25697	1.25919	.1	1.27535	1.27761

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
.2	1.27594	1.27819	61.5	1.29532	1.29761
.3	1.27652	1.27878	.6	1.29591	1.29820
.4	1.27710	1.27936	.7	1.29651	1.29880
			.8	1.29710	1.29940
58.5	1.27768	1.27994	.9	1.29770	1.29999
.6	1.27826	1.28052			
.7	1.27884	1.28111	62.0	1.29829	1.30059
.8	1.27943	1.28169	.1	1.29889	1.30118
.9	1.28001	1.28228	.2	1.29948	1.30178
			.3	1.30008	1.30238
59.0	1.28060	1.28286	.4	1.30068	1.30298
.1	1.28118	1.28345			
.2	1.28176	1.28404	62.5	1.30127	1.30358
.3	1.28235	1.28462	.6	1.30187	1.30418
.4	1.28294	1.28520	.7	1.30247	1.30477
			.8	1.30307	1.30537
59.5	1.28352	1.28579	.9	1.30367	1.30597
.6	1.28411	1.28638			
.7	1.28469	1.28697	63.0	1.30427	1.30657
.8	1.28528	1.28755	.1	1.30487	1.30718
.9	1.28587	1.28814	.2	1.30547	1.30778
			.3	1.30607	1.30838
60.0	1.28646	1.28873	.4	1.30667	1.30898
.1	1.28704	1.28932			
.2	1.28763	1.28991	63.5	1.30727	1.30958
.3	1.28822	1.29050	.6	1.30787	1.31019
.4	1.28881	1.29109	.7	1.30848	1.31079
			.8	1.30908	1.31139
60.5	1.28940	1.29168	.9	1.30968	1.31200
.6	1.28999	1.29227			
.7	1.29058	1.29286	64.0	1.31028	1.31260
.8	1.29117	1.29346	.1	1.31088	1.31320
.9	1.29176	1.29405	.2	1.31149	1.31381
			.3	1.31209	1.31441
61.0	1.29235	1.29464	.4	1.31270	1.31502
.1	1.29295	1.29523			
.2	1.29354	1.29583	64.5	1.31330	1.31563
.3	1.29413	1.29642	.6	1.31391	1.31623
.4	1.29472	1.29701	.7	1.31452	1.31684

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
.8	1.31512	1.31745	68.0	1.33472	1.33708
.9	1.31573	1.31806	.1	1.33534	1.33770
			.2	1.33596	1.33832
65.0	1.31633	1.31866	.3	1.33658	1.33894
.1	1.31694	1.31927	.4	1.33720	1.33957
.2	1.31755	1.31988			
.3	1.31816	1.32049	68.5	1.33782	1.34019
.4	1.31877	1.32110	.6	1.33844	1.34081
			.7	1.33906	1.34143
65.5	1.31937	1.32171	.8	1.33968	1.34205
.6	1.31998	1.32232	.9	1.34031	1.34268
.7	1.32059	1.32293			
.8	1.32120	1.32354	69.0	1.34093	1.34330
.9	1.32181	1.32415	.1	1.34155	1.34392
			.2	1.34217	1.34455
66.0	1.32242	1.32476	.3	1.34280	1.34517
.1	1.32304	1.32538	.4	1.34342	1.34580
.2	1.32365	1.32599			
.3	1.32426	1.32660	69.5	1.34405	1.34642
.4	1.32487	1.32722	.6	1.34467	1.34705
			.7	1.34530	1.34768
66.5	1.32548	1.32783	.8	1.34592	1.34830
.6	1.32610	1.32844	.9	1.34655	1.34893
.7	1.32671	1.32906			
.8	1.32732	1.32967	70.0	1.34717	1.34956
.9	1.32794	1.33029	.1	1.34780	1.35019
			.2	1.34843	1.35081
67.0	1.32855	1.33090	.3	1.34906	1.35144
.1	1.32917	1.33152	.4	1.34968	1.35207
.2	1.32978	1.33214			
.3	1.33040	1.33275	70.5	1.35031	1.35270
.4	1.33102	1.33337	.6	1.35094	1.35333
			.7	1.35157	1.35396
67.5	1.33163	1.33399	.8	1.35220	1.35459
.6	1.33225	1.33460	.9	1.35283	1.35522
.7	1.33287	1.33523			
.8	1.33348	1.33584	71.0	1.35346	1.35585
.9	1.33410	1.33646	.1	1.35409	1.35648

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
.2	1.35472	1.35711	.4	1.37510	1.37754
.3	1.35535	1.35775			
.4	1.35598	1.35838	74.5	1.37575	1.37818
			.6	1.37693	1.37883
71.5	1.35661	1.35901	.7	1.37704	1.37947
.6	1.35724	1.35964	.8	1.37768	1.38012
.7	1.35788	1.36028	.9	1.37833	1.38076
.8	1.35851	1.36091			
.9	1.35914	1.36155	75.0	1.37897	1.38141
			.1	1.37962	1.38206
72.0	1.35978	1.36218	.2	1.38026	1.38270
.1	1.36041	1.36282	.3	1.38091	1.38335
.2	1.36105	1.36346	.4	1.38156	1.38400
.3	1.36168	1.36409			
.4	1.36232	1.36473	75.5	1.38220	1.38465
			.6	1.38285	1.38530
72.5	1.36295	1.36536	.7	1.38350	1.38595
.6	1.36359	1.36600	.8	1.38415	1.38660
.7	1.36423	1.36664	.9	1.38480	1.38725
.8	1.36486	1.36728			
.9	1.36550	1.36792	76.0	1.38545	1.38790
			.1	1.38610	1.38855
73.0	1.36614	1.36856	.2	1.38675	1.38920
.1	1.36678	1.36919	.3	1.38740	1.38985
.2	1.36742	1.36983	.4	1.38805	1.39050
.3	1.36805	1.37047			
.4	1.36869	1.37111	76.5	1.38870	1.39115
			.6	1.38935	1.39180
73.5	1.36933	1.37176	.7	1.39000	1.39246
.6	1.36997	1.37240	.8	1.39065	1.39311
.7	1.37061	1.37304	.9	1.39130	1.39376
.8	1.37125	1.37368			
.9	1.37189	1.37432	77.0	1.39196	1.39442
			.1	1.39261	1.39507
74.0	1.37254	1.37496	.2	1.39326	1.39573
.1	1.37318	1.37561	.3	1.39392	1.39638
.2	1.37382	1.37625	.4	1.39457	1.39704
.3	1.37446	1.37689			

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
77.5	1.39523	1.39769	.8	1.41704	1.41955
.6	1.39588	1.39835	.9	1.41771	1.42022
.7	1.39654	1.39901			
.8	1.39719	1.39966	81.0	1.41837	1.42088
.9	1.39785	1.40032	.1	1.41904	1.42155
			.2	1.41971	1.42222
78.0	1.39850	1.40098	.3	1.42038	1.42289
.1	1.39916	1.40164	.4	1.42105	1.42356
.2	1.39982	1.40230			
.3	1.40048	1.40295	81.5	1.42172	1.42423
.4	1.40113	1.40361	.6	1.42239	1.42490
			.7	1.42306	1.42558
78.5	1.40179	1.40427	.8	1.42373	1.42625
.6	1.40245	1.40493	.9	1.42440	1.42692
.7	1.40311	1.40559			
.8	1.40377	1.40626	82.0	1.42507	1.42759
.9	1.40443	1.40691	.1	1.42574	1.42827
			.2	1.42642	1.42894
79.0	1.40509	1.40758	.3	1.42709	1.42961
.1	1.40575	1.40824	.4	1.42776	1.43029
.2	1.40641	1.40890			
.3	1.40707	1.40956	82.5	1.42844	1.43096
.4	1.40774	1.41023	.6	1.42911	1.43164
			.7	1.42978	1.43231
79.5	1.40840	1.41089	.8	1.43046	1.43298
.6	1.40906	1.41155	.9	1.43113	1.43366
.7	1.40972	1.41222			
.8	1.41039	1.41288	83.0	1.43181	1.43434
.9	1.41105	1.41355	.1	1.43248	1.43502
			.2	1.43316	1.43569
80.0	1.41172	1.41421	.3	1.43384	1.43637
.1	1.41238	1.41488	.4	1.43451	1.43705
.2	1.41305	1.41554			
.3	1.41371	1.41621	83.5	1.43519	1.43773
.4	1.41437	1.41688	.6	1.43587	1.43841
			.7	1.43654	1.43908
80.5	1.41504	1.41754	.8	1.43722	1.43976
.6	1.41571	1.41821	.9	1.43790	1.44044
.7	1.41637	1.41888			

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
84.0	1.43858	1.44112	.2	1.46050	1.46308
.1	1.43926	1.44180	.3	1.46119	1.46377
.2	1.43994	1.44249	.4	1.46188	1.46446
.3	1.44062	1.44317			
.4	1.44130	1.44385	87.5	1.46257	1.46516
			.6	1.46326	1.46585
84.5	1.44198	1.44453	.7	1.46395	1.46654
.6	1.44266	1.44521	.8	1.46464	1.46724
.7	1.44334	1.44590	.9	1.46534	1.46793
.8	1.44402	1.44658			
.9	1.44470	1.44726	88.0	1.46603	1.46862
			.1	1.46673	1.46932
85.0	1.44539	1.44794	.2	1.46742	1.47002
.1	1.44607	1.44863	.3	1.46812	1.47071
.2	1.44675	1.44931	.4	1.46881	1.47141
.3	1.44744	1.45000			
.4	1.44812	1.45068	88.5	1.46950	1.47210
			.6	1.47020	1.47280
85.5	1.44881	1.45137	.7	1.47090	1.47350
.6	1.44949	1.45205	.8	1.47159	1.47420
.7	1.45018	1.45274	.9	1.47229	1.47489
.8	1.45086	1.45343			
.9	1.45154	1.45411	89.0	1.47299	1.47559
			.1	1.47368	1.47629
86.0	1.45223	1.45480	.2	1.47438	1.47699
.1	1.45292	1.45549	.3	1.47508	1.47769
.2	1.45360	1.45618	.4	1.47578	1.47839
.3	1.45429	1.45686			
.4	1.45498	1.45755	89.5	1.47648	1.47909
			.6	1.47718	1.47979
86.5	1.45567	1.45824	.7	1.47788	1.48049
.6	1.45636	1.45893	.8	1.47858	1.48119
.7	1.45704	1.45962	.9	1.47928	1.48189
.8	1.45773	1.46031			
.9	1.45842	1.46100	90.0	1.47998	1.48259
			.1	1.48068	1.48330
87.0	1.45911	1.46170	.2	1.48138	1.48400
.1	1.45980	1.46239	.3	1.48208	1.48470

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
.4	1.48278	1.48540	.6	1.50543	1.50810
			.7	1.50615	1.50881
90.5	1.48348	1.48611	.8	1.50686	1.50952
.6	1.48419	1.48681	.9	1.50757	1.51024
.7	1.48489	1.48752			
.8	1.48559	1.48822	94.0	1.50829	1.51096
.9	1.48630	1.48893	.1	1.50900	1.51167
			.2	1.50972	1.51239
91.0	1.48700	1.48963	.3	1.51044	1.51311
.1	1.48771	1.49034	.4	1.51115	1.51382
.2	1.48841	1.49104			
.3	1.48912	1.49175	94.5	1.51187	1.51454
.4	1.48982	1.49246	.6	1.51258	1.51526
			.7	1.51330	1.51598
91.5	1.49053	1.49316	.8	1.51402	1.51670
.6	1.49123	1.49387	.9	1.51474	1.51742
.7	1.49194	1.49458			
.8	1.49265	1.49529	95.0	1.51546	1.51844
.9	1.49336	1.49600	.1	1.51617	1.51886
			.2	1.51689	1.51958
92.0	1.49406	1.49671	.3	1.51761	1.52030
.1	1.49477	1.49741	.4	1.51833	1.52102
.2	1.49548	1.49812			
.3	1.49619	1.49883	95.5	1.51905	1.52174
.4	1.49690	1.49954	.6	1.51977	1.52246
			.7	1.52049	1.52318
92.5	1.49761	1.50026	.8	1.52121	1.52390
.6	1.49832	1.50097	.9	1.52193	1.52463
.7	1.49903	1.50168			
.8	1.49974	1.50239	96.0	1.52266	1.52535
.9	1.50045	1.50310	.1	1.52338	1.52607
			.2	1.52410	1.52680
93.0	1.50116	1.50381	.3	1.52482	1.52752
.1	1.50187	1.50453	.4	1.52555	1.52824
.2	1.50258	1.50524			
.3	1.50329	1.50595	96.5	1.52627	1.52897
.4	1.50401	1.50667	.6	1.52699	1.52969
			.7	1.52772	1.53042
93.5	1.50472	1.50738			

Table III-A (Continued)

Degrees Brix and Specific Gravity of Sugar Solutions at 20 °C

Degrees Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity at 20°/20°C	Degree Brix or Per Cent Sucrose by Weight	Specific Gravity at 20°/4°C	Specific Gravity st 20°/20°C
.8	1.52844	1.53114	98.5	1.54081	1.54353
.9	1.52917	1.53187	.6	1.54154	1.54426
			.7	1.54227	1.54499
97.0	1.52989	1.53260	.8	1.54300	1.54573
.1	1.53062	1.53332	.9	1.54373	1.54646
.2	1.53134	1.53405			
.3	1.53207	1.53478	99.0	1.54446	1.54719
.4	1.53279	1.53551	.1	1.54519	1.54793
			.2	1.54593	1.54866
97.5	1.53352	1.53623	.3	1.54666	1.54939
.6	1.53425	1.53696	.4	1.54739	1.55013
.7	1.53498	1.53769			
.8	1.53570	1.53842	99.5	1.54813	1.55087
.9	1.53643	1.53915	.6	1.54886	1.55160
			.7	1.54960	1.55234
98.0	1.53716	1.53988	.8	1.55033	1.55307
.1	1.53789	1.54061	.9	1.55106	1.55381
.2	1.53862	1.54134			
.3	1.53935	1.54207	100.0	1.55180	1.55454
.4	1.54008	1.54280			

Table III-B

Brix and Specific Gravity at 27.5 °/27.5 °C

Brix	Specific* Gravity	Brix	Specific Gravity	Brix	Specific Gravity	Brix	Specific Gravity
0.0	1.00000	8.0	1.03167	16.0	1.06508	24.0	1.10048
.2	1.00078	.2	1.03248	.2	1.06594	.2	1.10140
.4	1.00155	.4	1.03330	.4	1.06680	.4	1.10231
.6	1.00233	.6	1.03411	.6	1.06767	.6	1.10322
.8	1.00311	.8	1.03493	.8	1.06853	.8	1.10414
1.0	1.00389	9.0	1.03574	17.0	1.06940	25.0	1.10551
.2	1.00466	.2	1.03656	.2	1.07026	.2	1.10597
.4	1.00544	.4	1.03738	.4	1.07113	.4	1.10689
.6	1.00622	.6	1.03820	.6	1.07200	.6	1.10781
.8	1.00700	.8	1.03902	.8	1.07287	.8	1.10873
2.0	1.00778	10.0	1.03984	18.0	1.07374	26.0	1.10965
.2	1.00856	.2	1.04067	.2	1.07461	.2	1.11058
.4	1.00934	.4	1.04149	.4	1.07549	.4	1.11151
.6	1.01013	.6	1.04232	.6	1.07636	.6	1.11244
.8	1.01091	.8	1.04314	.8	1.07724	.8	1.11336
3.0	1.01169	11.0	1.04397	19.0	1.07812	27.0	1.11429
.2	1.01248	.2	1.04480	.2	1.07900	.2	1.11522
.4	1.01327	.4	1.04564	.4	1.07988	.4	1.11616
.6	1.01406	.6	1.04647	.6	1.08076	.6	1.11709
.8	1.01485	.8	1.04730	.8	1.08164	.8	1.11802
4.0	1.01561	12.0	1.04813	20.0	1.08253	28.0	1.11896
.2	1.01643	.2	1.04897	.2	1.08341	.2	1.11989
.4	1.01722	.4	1.04981	.4	1.08430	.4	1.12083
.6	1.01802	.6	1.05065	.6	1.08519	.6	1.12177
.8	1.01881	.8	1.05148	.8	1.08608	.8	1.12271
5.0	1.01960	13.0	1.05232	21.0	1.08697	29.0	1.12365
.2	1.02040	.2	1.05317	.2	1.08786	.2	1.12460
.4	1.02120	.4	1.05401	.4	1.08876	.4	1.12555
.6	1.02200	.6	1.05485	.6	1.08965	.6	1.12649
.8	1.02280	.8	1.05570	.8	1.09055	.8	1.12744
6.0	1.02360	14.0	1.05654	22.0	1.09144	30.0	1.12839
.2	1.02440	.2	1.05739	.2	1.09234	.2	1.12934
.4	1.02521	.4	1.05824	.4	1.09324	.4	1.13030
.6	1.02601	.6	1.05909	.6	1.09414	.6	1.13125
.8	1.02682	.8	1.05994	.8	1.09504	.8	1.13221
7.0	1.02762	15.0	1.06080	23.0	1.09595	31.0	1.13316
.2	1.02843	.2	1.06165	.2	1.09685	.2	1.13412
.4	1.02924	.4	1.06251	.4	1.09776	.4	1.13508
.6	1.03005	.6	1.06336	.6	1.09867	.6	1.13604
.8	1.03086	.8	1.06422	.8	1.09957	.8	1.13700

* Calculated from the table of the Kaiserliche Normaleichungskommission to apparent degrees Brix and Specific Gravity of sugar solutions weighed in air with brass weights at 27.5 °C

[Taken from Cane Sugar Hand Book by Spencer & Meade, Eighth Edition 1965]

Table III-B (Continued)

Brix and Specific Gravity at 27.5 °/27.5 °C

Brix	Specific Gravity	Brix	Specific Gravity	Brix	Specific Gravity	Brix	Specific Gravity
32.0	1.13797	41.0	1.18281	50.0	1.23077	59.0	1.28178
.2	1.13893	.2	1.18384	.2	1.23187	.2	1.28295
.4	1.13990	.4	1.18488	.4	1.23298	.4	1.28412
.6	1.14087	.6	1.18592	.6	1.23408	.6	1.28530
.8	1.14184	.8	1.18695	.8	1.23518	.8	1.28647
33.0	1.14281	42.0	1.18799	51.0	1.23629	60.0	1.28764
.2	1.14378	.2	1.18903	.2	1.23740	.2	1.28882
.4	1.14476	.4	1.19007	.4	1.23851	.4	1.29000
.6	1.14573	.6	1.19112	.6	1.23962	.6	1.29118
.8	1.14671	.8	1.19216	.8	1.24073	.8	1.29236
34.0	1.14768	43.0	1.19320	52.0	1.24184	61.0	1.29354
.2	1.14866	.2	1.19425	.2	1.24295	.2	1.29473
.4	1.14965	.4	1.19530	.4	1.24407	.4	1.29592
.6	1.15063	.6	1.19635	.6	1.24519	.6	1.29710
.8	1.15161	.8	1.19740	.8	1.24631	.8	1.29829
35.0	1.15259	44.0	1.19845	53.0	1.24743	62.0	1.29948
.2	1.15358	.2	1.19951	.2	1.24855	.2	1.30067
.4	1.15457	.4	1.20057	.4	1.24968	.4	1.30187
.6	1.15556	.6	1.20163	.6	1.25080	.6	1.30307
.8	1.15655	.8	1.20269	.8	1.25193	.8	1.30426
36.0	1.15753	45.0	1.20375	54.0	1.25305	63.0	1.30546
.2	1.15853	.2	1.20481	.2	1.25419	.2	1.30666
.4	1.15952	.4	1.20588	.4	1.25532	.4	1.30786
.6	1.16052	.6	1.20695	.6	1.25645	.6	1.30907
.8	1.16152	.8	1.20801	.8	1.25758	.8	1.31027
37.0	1.16251	46.0	1.20908	55.0	1.25872	64.0	1.31147
.2	1.16351	.2	1.21015	.2	1.25986	.2	1.31269
.4	1.16454	.4	1.21122	.4	1.26100	.4	1.31390
.6	1.16552	.6	1.21230	.6	1.26214	.6	1.31511
.8	1.16652	.8	1.21337	.8	1.26328	.8	1.31632
38.0	1.16753	47.0	1.21445	56.0	1.26443	65.0	1.31753
.2	1.16854	.2	1.21553	.2	1.26557	.2	1.31875
.4	1.16955	.4	1.21661	.4	1.26672	.4	1.31997
.6	1.17056	.6	1.21769	.6	1.26787	.6	1.32119
.8	1.17157	.8	1.21877	.8	1.26902	.8	1.32240
39.0	1.17258	48.0	1.21985	57.0	1.27017	66.0	1.32362
.2	1.17360	.2	1.22094	.2	1.27133	.2	1.32485
.4	1.17462	.4	1.22203	.4	1.27249	.4	1.32608
.6	1.17564	.6	1.22311	.6	1.27364	.6	1.32730
.8	1.17666	.8	1.22420	.8	1.27480	.8	1.32853
40.0	1.17768	49.0	1.22529	58.0	1.27596	67.0	1.32975
.2	1.17870	.2	1.22639	.2	1.27712	.2	1.33099
.4	1.17973	.4	1.22748	.4	1.27829	.4	1.33222
.6	1.18076	.6	1.22858	.6	1.27945	.6	1.33346
.8	1.18178	.8	1.22968	.8	1.28061	.8	1.33469

Table III-B (Concluded)

Brix and Specific Gravity at 27.5 °/27.5 °C

Brix	Specific Gravity	Brix	Specific Gravity	Brix	Specific Gravity	Brix	Specific Gravity
68.0	1.33593	76.0	1.38668	84.0	1.43985	92.0	1.49538
.2	1.33717	.2	1.38798	.2	1.44121	.2	1.49680
.4	1.33841	.4	1.38928	.4	1.44257	.4	1.49822
.6	1.33965	.6	1.39058	.6	1.44393	.6	1.49964
.8	1.34089	.8	1.39188	.8	1.44530	.8	1.50107
69.0	1.34213	77.0	1.39319	85.0	1.44666	93.0	1.50249
.2	1.34338	.2	1.39450	.2	1.44803	.2	1.50391
.4	1.34463	.4	1.39581	.4	1.44940	.4	1.50534
.6	1.34588	.6	1.39712	.6	1.45077	.6	1.50677
.8	1.34713	.8	1.39843	.8	1.45214	.8	1.50820
70.0	1.34838	78.0	1.39974	86.0	1.45351	94.0	1.50962
.2	1.34964	.2	1.40106	.2	1.45489	.2	1.51106
.4	1.35090	.4	1.40238	.4	1.45627	.4	1.51249
.6	1.35216	.6	1.40370	.6	1.45764	.6	1.51393
.8	1.35341	.8	1.40501	.8	1.45902	.8	1.51536
71.0	1.35467	79.0	1.40633	87.0	1.46040	95.0	1.51680
.2	1.35593	.2	1.40766	.2	1.46178	.2	1.51824
.4	1.35720	.4	1.40898	.4	1.46317	.4	1.51968
.6	1.35846	.6	1.41031	.6	1.46455	.6	1.52112
.8	1.35973	.8	1.41163	.8	1.46594	.8	1.52256
72.0	1.36099	80.0	1.41296	88.0	1.46732	96.0	1.52401
.2	1.36226	.2	1.41429	.2	1.46872	.2	1.52546
.4	1.36354	.4	1.41562	.4	1.47011	.4	1.52960
.6	1.36481	.6	1.41696	.6	1.47150	.6	1.52835
.8	1.36608	.8	1.41829	.8	1.47289	.8	1.52980
73.0	1.36736	81.0	1.41962	89.0	1.47428	97.0	1.53125
.2	1.36864	.2	1.42096	.2	1.47568	.2	1.53271
.4	1.36992	.4	1.42231	.4	1.47708	.4	1.53416
.6	1.37120	.6	1.42365	.6	1.47848	.6	1.53562
.8	1.37248	.8	1.42499	.8	1.47988	.8	1.53708
74.0	1.37376	82.0	1.42633	90.0	1.48128	98.0	1.53853
.2	1.37504	.2	1.42768	.2	1.48269	.2	1.53999
.4	1.37633	.4	1.42902	.4	1.48409	.4	1.54146
.6	1.37762	.6	1.43037	.6	1.48550	.6	1.54292
.8	1.37890	.8	1.43172	.8	1.48691	.8	1.54438
75.0	1.38020	83.0	1.43307	91.0	1.48831	99.0	1.54584
.2	1.38149	.2	1.43442	.2	1.48973	.2	1.54731
.4	1.38279	.4	1.43578	.4	1.49114	.4	1.54878
.6	1.38409	.6	1.43713	.6	1.49255	.6	1.55025
.8	1.38538	.8	1.43849	.8	1.49397	.8	1.55172
						100.0	1.55319

Table IV-A

Table for the Correction of Readings of Brix Scale for Variation in Temperature from 20 °C

Temp. °C	5	10	15	20	25	30	35	40	45	50	55	60	70
0	0.49	0.65	0.77	0.89	0.99	1.08	1.16	1.24	1.31	1.37	1.41	1.44	1.48
5	.47	.56	.65	.73	.80	.86	.91	.97	1.01	1.05	1.08	1.10	1.14
10	.38	.43	.48	.52	.57	.60	.64	.67	.70	.72	.74	.75	.77
11	.35	.40	.44	.48	.51	.55	.58	.60	.63	.65	.66	.68	.70
12	.32	.36	.40	.43	.46	.50	.52	.54	.56	.58	.59	.60	.62
13	.29	.32	.35	.38	.41	.44	.46	.48	.49	.51	.52	.53	.55
14	.26	.29	.31	.34	.36	.38	.40	.41	.42	.44	.45	.46	.47
15	.22	.24	.26	.28	.30	.32	.33	.34	.36	.36	.37	.38	.39
16	.18	.20	.22	.23	.25	.26	.27	.28	.28	.29	.30	.31	.32
17	.14	.15	.16	.18	.19	.20	.20	.21	.21	.22	.23	.23	.24
18	.10	.10	.11	.12	.13	.13	.14	.14	.14	.15	.15	.15	.16
19	.05	.05	.05	.06	.06	.07	.07	.07	.07	.08	.08	.08	.08
Add the correction to the readings above 20 °C., and subtract the correction from those below this temperature													
21	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09
22	.10	.11	.12	.12	.13	.14	.14	.15	.15	.16	.16	.16	.16
23	.16	.17	.17	.19	.20	.21	.21	.22	.23	.24	.24	.24	.24
24	.22	.23	.24	.26	.27	.28	.29	.30	.31	.32	.32	.32	.32
25	.28	.30	.31	.32	.34	.35	.36	.38	.38	.39	.39	.40	.39
26	.34	.36	.37	.40	.40	.42	.44	.46	.47	.47	.48	.48	.48
27	.41	.42	.44	.46	.48	.50	.52	.54	.54	.55	.56	.56	.56
28	.47	.49	.51	.54	.56	.58	.60	.61	.62	.63	.64	.64	.64
29	.55	.56	.59	.61	.63	.66	.68	.70	.70	.70	.72	.72	.72
30	.62	.63	.66	.68	.71	.73	.76	.78	.78	.79	.80	.80	.81
35	1.01	1.06	1.10	1.13	1.16	1.18	1.20	1.21	1.22	1.22	1.23	1.23	1.22
40	1.45	1.47	1.51	1.54	1.57	1.60	1.62	1.64	1.65	1.65	1.65	1.66	1.65
45	1.94	1.96	2.00	2.03	2.05	2.07	2.09	2.10	2.10	2.10	2.10	2.10	2.08
50	2.48	2.50	2.53	2.56	2.57	2.58	2.59	2.59	2.58	2.58	2.57	2.56	2.52
55	3.07	3.09	3.12	3.12	3.12	3.12	3.11	3.10	3.08	3.07	3.05	3.03	2.97
60	3.72	3.73	3.73	3.72	3.70	3.67	3.65	3.62	3.60	3.57	3.54	3.54	3.43
65	4.4	4.4	4.4	4.4	4.4	4.3	4.2	4.2	4.1	4.1	4.0	4.0	3.9
70	5.1	5.1	5.0	5.0	5.0	4.9	4.8	4.8	4.7	4.7	4.6	4.6	4.4
75	6.0	6.0	5.9	5.8	5.8	5.7	5.6	5.5	5.4	5.4	5.3	5.2	5.0
80	7.0	7.0	6.9	6.8	6.7	6.6	6.4	6.3	6.2	6.1	6.0	5.9	5.6

Table IV-B

Temerature Corrections for Brix Readings (Standard 27.5 °C)

Temp.,	Observed Degrees Brix													
°C	0	5	10	15	20	25	30	35	40	45	50	55	60	70
	Substract from the Readings													
10	0.75	0.82	0.89	0.96	1.02	1.08	1.14	1.20	1.24	1.28	1.31	1.33	1.35	1.37
11	0.74	0.79	0.86	0.92	0.98	1.03	1.09	1.14	1.18	1.21	1.24	1.26	1.28	1.30
12	0.72	0.76	0.82	0.88	0.93	0.98	1.04	1.08	1.12	1.14	1.17	1.19	1.20	1.22
13	0.69	0.73	0.78	0.84	0.88	0.93	0.98	1.02	1.06	1.07	1.10	1.12	1.13	1.15
14	0.66	0.70	0.74	0.79	0.83	0.88	0.92	0.96	0.99	1.00	1.03	1.05	1.06	1.07
15	0.63	0.66	0.70	0.74	0.78	0.82	0.86	0.89	0.92	0.93	0.95	0.97	0.98	0.99
16	0.60	0.62	0.66	0.69	0.73	0.76	0.80	0.83	0.86	0.86	0.88	0.90	0.91	0.92
17	0.56	0.58	0.61	0.64	0.68	0.70	0.74	0.77	0.79	0.79	0.81	0.83	0.83	0.84
18	0.52	0.54	056	0.59	0.62	0.64	0.68	0.70	0.72	0.72	0.74	0.75	0.75	0.76
19	0.48	0.49	0.51	0.54	0.56	0.58	0.61	0.63	0.65	0.65	0.67	0.68	0.68	0.68
20	0.43	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.58	0.59	0.60	0.60	0.60
21	0.38	0.39	0.41	0.42	0.44	0.46	0.47	0.49	0.51	0.51	0.51	0.52	0.52	0.52
22	0.33	0.34	0.35	0.36	0.38	0.40	0.40	0.42	0.43	0.43	0.43	0.44	0.44	0.44
23	0.28	0.28	0.29	0.30	0.32	0.33	0.33	0.35	0.36	0.36	0.36	0.36	0.36	0.36
24	0.22	0.22	0.23	0.24	0.25	0.26	0.26	0.27	0.28	0.28	0.28	0.28	0.28	0.28
25	0.16	0.16	0.17	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
26	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
27	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Add to the Readings													
28	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
29	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
30	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
31	0.25	0.25	0.25	0.26	0.26	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.29
32	0.32	0.33	0.33	0.34	0.34	0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.37

Table IV-B (Continued)

Temerature Corrections for Brix Readings (Standard 27.5 °C)

Temp.,	Observed Degrees Brix													
°C	0	5	10	15	20	25	30	35	40	45	50	55	60	70
33	0.40	0.41	0.41	0.42	0.42	0.43	0.43	0.44	0.44	0.44	0.44	0.44	0.44	0.45
34	0.48	0.49	0.49	0.50	0.50	0.51	0.52	0.52	0.52	0.53	0.53	0.53	0.53	0.53
35	0.56	0.57	0.57	0.58	0.59	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.62
36	0.64	0.65	0.65	0.67	0.68	0.69	0.70	0.70	0.70	0.71	0.70	0.70	0.70	0.70
37	0.72	0.74	0.74	0.76	0.77	0.78	0.79	0.79	0.79	0.80	0.79	0.79	0.79	0.79
38	0.81	0.83	0.83	0.85	0.86	0.87	0.88	0.88	0.88	0.89	0.88	0.88	0.88	0.88
39	0.90	0.92	0.92	0.94	0.95	0.96	0.97	0.97	0.97	0.98	0.97	0.97	0.97	0.97
40	0.99	1.01	1.01	1.03	1.04	1.05	1.06	1.06	1.06	1.07	1.06	1.05	1.05	1.05
45	1.48	1.50	1.50	1.52	1.53	1.53	1.53	1.53	1.52	1.52	1.51	1.50	1.50	1.48
50	2.03	2.04	2.04	2.05	2.06	2.05	2.04	2.03	2.01	2.00	1.99	1.97	1.96	1.92
55	2.62	2.63	2.63	2.64	2.62	2.60	2.58	2.55	2.52	2.50	2.48	2.45	2.43	2.37
60	3.26	3.28	3.27	3.25	3.22	3.18	3.13	3.09	3.04	3.02	2.98	2.94	2.90	2.83
65	3.95	3.98	3.95	3.90	3.86	3.79	3.71	3.66	3.58	3.56	3.50	3.44	3.38	3.30
70	4.70	4.74	4.70	4.60	4.54	4.44	4.32	4.24	4.14	4.12	4.03	3.96	3.87	3.78
75	5.50	5.56	4.48	5.34	5.26	5.12	4.95	4.86	4.72	4.70	4.57	4.50	4.37	4.27
80	6.35	6.41	6.32	6.12	6.02	5.84	5.62	5.51	5.32	5.30	5.14	5.04	4.88	4.77

[Taken from Cane Sugar Hand Book by Spencer & Meade, Eighth Edition, 1945]

Table V-A

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

This table is arranged after Schmitz, but no allowance is made for variation in the rotatory power of sucrose. The investigation of Brown* show such allowance to be unnecessary.

Pol. Reading	Degrees Brix and Per Cent Sucrose																		Pol. Reading
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.	
1	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1
2	0.52	0.52	0.52	0.52	0.52	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.50	0.50	0.50	0.50	2
3	0.78	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.76	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.75	3
4	1.04	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.00	1.00	4
5	1.29	1.29	1.29	1.29	1.29	1.28	1.28	1.28	1.28	1.27	1.27	1.27	1.27	1.26	1.26	1.26	1.25	1.25	5
6	—	1.55	1.55	1.55	1.55	1.54	1.54	1.53	1.53	1.53	1.53	1.52	1.52	1.51	1.51	1.51	1.51	1.50	6
7	—	1.81	1.81	1.80	1.80	1.80	1.80	1.79	1.79	1.79	1.78	1.77	1.77	1.77	1.76	1.76	1.76	1.75	7
8	—	—	2.06	2.06	2.06	2.05	2.05	2.04	2.04	2.04	2.03	2.03	2.02	2.02	2.02	2.01	2.01	2.00	8
9	—	—	—	2.32	2.31	2.31	2.30	2.30	2.30	2.29	2.28	2.28	2.28	2.27	2.27	2.26	2.26	2.25	9
10	—	—	—	2.58	2.57	2.57	2.56	2.56	2.55	2.55	2.54	2.54	2.53	2.52	2.52	2.51	2.51	2.50	10
11	—	—	—	2.83	2.83	2.82	2.82	2.81	2.81	2.80	2.80	2.79	2.78	2.78	2.77	2.77	2.76	2.75	11
12	—	—	—	—	3.08	3.08	3.07	3.06	3.06	3.05	3.05	3.04	3.04	3.03	3.02	3.02	3.01	3.00	12
13	—	—	—	—	3.34	3.33	3.33	3.32	3.31	3.30	3.30	3.29	3.29	3.28	3.28	3.27	3.26	3.26	13
14	—	—	—	—	—	3.59	3.58	3.58	3.57	3.56	3.56	3.55	3.54	3.53	3.52	3.52	3.51	3.51	14
15	—	—	—	—	—	3.84	3.83	3.83	3.82	3.82	3.82	3.81	3.79	3.78	3.78	3.77	3.76	3.76	15
16	—	—	—	—	—	—	4.09	4.09	4.08	4.07	4.07	4.06	4.05	4.04	4.03	4.02	4.01	4.01	16
17	—	—	—	—	—	—	—	4.34	4.33	4.33	4.32	4.31	4.30	4.29	4.28	4.28	4.27	4.26	17
18	—	—	—	—	—	—	—	4.59	4.59	4.58	4.57	4.56	4.55	4.54	4.54	4.53	4.52	4.51	18
19	—	—	—	—	—	—	—	—	4.84	4.84	4.83	4.82	4.81	4.80	4.79	4.78	4.77	4.76	19
20	—	—	—	—	—	—	—	—	5.10	5.09	5.08	5.07	5.06	5.05	5.04	5.03	5.02	5.01	20
21	—	—	—	—	—	—	—	—	5.36	5.34	5.33	5.32	5.30	5.30	5.29	5.28	5.27	5.26	21
22	—	—	—	—	—	—	—	—	—	5.60	5.59	5.58	5.57	5.55	5.54	5.53	5.52	5.51	22
23	—	—	—	—	—	—	—	—	—	5.85	5.84	5.83	5.82	5.81	5.80	5.70	5.77	5.76	23

* Handbook of Sugar Analysis, 118.

Table V-A (Continued)

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

Degrees Brix from 0.5 to 12.0	
Tenths of the Polariscope Reading	Per Cent Sucrose
0.1	0.025
0.2	0.051
0.3	0.076
0.4	0.102
0.5	0.127
0.6	0.152
0.7	0.178
0.8	0.203
0.9	0.228

Instructions

Note the Degree Brix of the solution. To an indefinite volume of solution, contained in a narrow cylinder or other vessel that may be readily closed by the plam of hand, add sufficient dry subacetate of lead in powder and little dry sand; cover the mouth of the cylinder with the hand and shake to thoroughly mix the solution with the lead. Filter and polarise, using a 200 mm tube. To the number in the Table opposite the integral part of the polariscope reading and under the degree Brix nearest that observed, add the number in the small table corresponding to the tenth of reading. The sum of those numbers is the per cent sucrose in the solution.

6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.	
5.85	5.84	5.83	5.82	5.81	5.80	5.79	5.77	5.76	23
—	6.10	6.09	6.07	6.06	6.05	6.04	6.02	6.01	24
—	6.35	6.34	6.33	6.31	6.30	6.29	6.27	6.26	25
—	—	6.59	6.58	6.57	6.55	6.54	6.52	6.51	26
—	—	6.84	6.83	6.82	6.80	6.79	6.77	6.76	27
—	—	—	7.08	7.07	7.05	7.04	7.03	7.02	28
—	—	—	7.34	7.33	7.31	7.29	7.28	7.27	29
—	—	—	—	7.57	7.55	7.54	7.53	7.52	30
—	—	—	—	7.82	7.81	7.79	7.78	7.76	31
—	—	—	—	—	8.06	8.04	8.03	8.02	32
—	—	—	—	—	8.31	8.30	8.28	8.27	33
—	—	—	—	—	—	8.55	8.53	8.52	34
—	—	—	—	—	—	—	8.78	8.77	35
—	—	—	—	—	—	—	9.03	9.02	36
—	—	—	—	—	—	—	9.28	9.27	37
—	—	—	—	—	—	—	—	9.51	38
—	—	—	—	—	—	—	—	9.76	39

Table V-A (Continued)

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

Pol. Reading	Degrees Brix and per cent Sucrose																			Pol. Reading
	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.5	20.0	
1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	1
2	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	2
3	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.73	0.73	0.73	0.73	0.73	0.73	0.72	0.72	3
4	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.96	0.96	4
5	1.25	1.25	1.25	1.24	1.24	1.24	1.24	1.24	1.23	1.23	1.23	1.22	1.22	1.22	1.22	1.21	1.21	1.21	1.20	5
6	1.50	1.50	1.50	1.49	1.49	1.49	1.48	1.48	1.48	1.48	1.47	1.47	1.46	1.46	1.46	1.45	1.45	1.45	1.44	6
7	1.75	1.75	1.75	1.74	1.74	1.74	1.73	1.73	1.72	1.72	1.71	1.71	1.70	1.70	1.69	1.69	1.69	1.69	1.68	7
8	2.00	2.00	1.99	1.98	1.98	1.98	1.98	1.97	1.97	1.97	1.96	1.96	1.95	1.95	1.94	1.94	1.94	1.93	1.92	8
9	2.25	2.24	2.24	2.24	2.24	2.24	2.23	2.22	2.22	2.21	2.21	2.21	2.20	2.20	2.19	2.19	2.18	2.18	2.17	2.16	9
10	2.50	2.49	2.49	2.48	2.48	2.48	2.47	2.47	2.46	2.46	2.45	2.45	2.44	2.44	2.43	2.43	2.42	2.42	2.41	2.41	10
11	2.75	2.74	2.73	2.73	2.72	2.72	2.71	2.71	2.70	2.70	2.69	2.68	2.68	2.67	2.67	2.67	2.66	2.66	2.65	2.64	11
12	3.00	2.99	2.98	2.98	2.97	2.97	2.96	2.96	2.95	2.95	2.94	2.93	2.93	2.92	2.92	2.91	2.91	2.90	2.89	2.89	12
13	3.25	3.24	3.23	3.23	3.22	3.21	3.20	3.20	3.19	3.19	3.18	3.17	3.17	3.16	3.16	3.15	3.14	3.14	3.13	3.13	13
14	3.50	3.50	3.49	3.48	3.47	3.46	3.45	3.45	3.44	3.43	3.42	3.42	3.41	3.41	3.41	3.40	3.39	3.38	3.37	3.37	14
15	3.75	3.74	3.73	3.72	3.71	3.71	3.70	3.69	3.69	3.68	3.67	3.66	3.66	3.65	3.65	3.64	3.63	3.62	3.62	3.61	15
16	4.00	3.99	3.98	3.97	3.96	3.96	3.95	3.94	3.94	3.93	3.92	3.91	3.90	3.88	3.88	3.88	3.87	3.86	3.85	3.85	16
17	4.25	4.25	4.23	4.22	4.21	4.20	4.19	4.19	4.18	4.17	4.16	4.15	4.14	4.12	4.12	4.12	4.11	4.11	4.10	4.09	17
18	4.50	4.49	4.48	4.47	4.46	4.45	4.44	4.44	4.43	4.42	4.41	4.40	4.39	4.37	4.37	4.37	4.35	4.35	4.34	4.33	18
19	4.75	4.74	4.73	4.72	4.71	4.70	4.69	4.68	4.67	4.66	4.65	4.64	4.63	4.61	4.61	4.61	4.60	4.59	4.58	4.57	19
20	5.00	4.99	4.98	4.97	4.96	4.95	4.94	4.93	4.92	4.91	4.90	4.89	4.88	4.86	4.86	4.85	4.84	4.83	4.82	4.81	20
21	5.25	5.23	5.22	5.21	5.20	5.19	5.18	5.17	5.16	5.15	5.14	5.13	5.12	5.10	5.10	5.09	5.08	5.07	5.06	5.05	21
22	5.50	5.48	5.47	5.46	5.42	5.44	5.43	5.42	5.41	5.40	5.39	5.38	5.37	5.35	5.35	5.34	5.32	5.31	5.30	5.29	22
23	5.75	5.73	5.72	5.71	5.70	5.69	5.68	5.67	5.66	5.65	5.64	5.62	5.61	5.59	5.58	5.58	5.56	5.55	5.54	5.53	23
24	6.00	5.98	5.97	5.96	5.95	5.94	5.93	5.92	5.91	5.90	5.89	5.87	5.86	5.84	5.83	5.82	5.81	8.80	5.79	5.77	24
25	6.25	6.23	6.22	6.21	6.20	6.18	6.17	6.16	6.15	6.14	6.13	6.11	6.10	6.08	6.07	6.06	6.05	6.04	6.03	6.01	25
26	6.50	6.49	6.48	6.46	6.44	6.43	6.42	6.41	6.40	6.39	6.38	6.36	6.34	6.33	6.32	6.30	6.29	6.28	6.27	6.26	26
27	6.75	6.74	6.72	6.70	6.69	6.68	6.67	6.65	6.54	6.63	6.62	6.60	6.59	6.57	6.56	6.55	6.54	6.52	6.51	6.50	27
28	7.00	6.98	6.97	6.95	6.94	6.93	6.93	6.90	6.89	6.87	6.86	6.85	6.84	6.82	6.81	6.79	6.77	6.73	6.75	6.74	28
29	7.25	7.23	7.22	7.20	7.19	7.17	7.16	7.15	7.14	7.12	7.11	7.09	7.08	7.06	7.05	7.03	7.02	7.01	6.99	6.98	29

Table V-A

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

Pol. Reading	Degrees Brix and Per Cent Sucrose																				Pol. Reading
	10.5	11.0	11.05	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	--20.0	
30	7.50	7.48	7.47	7.45	7.44	7.42	7.41	7.40	7.39	7.37	7.35	7.34	7.33	7.31	7.29	7.27	7.26	7.25	7.23	7.22	30
31	7.75	7.73	7.71	7.70	7.68	7.66	7.65	7.64	7.63	7.61	7.60	7.58	7.57	7.55	7.53	7.51	7.50	7.49	7.47	7.46	31
32	8.00	7.98	7.96	7.95	7.93	7.91	7.90	7.89	7.88	7.86	7.84	7.82	7.81	7.79	7.78	7.76	7.75	7.73	7.71	7.70	32
33	8.25	8.23	8.21	8.20	8.18	8.16	8.15	8.13	8.12	8.10	8.09	8.07	8.05	8.03	8.01	8.00	7.99	7.97	7.95	7.94	33
34	8.50	8.48	8.47	8.45	8.43	8.41	8.40	8.38	8.37	8.35	8.34	8.32	8.30	8.28	8.26	8.24	8.23	8.22	8.20	8.18	34
35	8.75	8.73	8.71	8.69	8.68	8.66	8.65	8.63	8.61	8.59	8.58	8.56	8.54	8.52	8.50	8.48	8.47	8.46	8.44	8.42	35
36	9.00	8.98	8.96	8.94	8.92	8.91	8.90	8.88	8.86	8.84	8.82	8.80	8.78	8.76	8.75	8.73	8.71	8.70	8.68	8.66	36
37	9.25	9.23	9.21	9.19	9.17	9.15	9.14	9.12	9.10	9.08	9.07	9.05	9.03	9.01	8.99	8.97	8.95	8.94	8.92	8.90	37
38	9.50	9.48	9.46	9.44	9.42	9.40	9.39	9.37	9.35	9.33	9.31	9.29	9.27	9.26	9.24	9.21	9.20	9.18	9.16	9.14	38
39	9.75	9.73	9.71	9.69	9.67	9.65	9.64	9.62	9.60	9.58	9.55	9.53	9.51	9.50	9.48	9.46	9.44	9.43	9.40	9.38	39

Degree Brix from 0.5 to 12.0		Degree Brix from 12.0 to 20.0	
Tenths of the Polariscope Reading	Per Cent Sucrose	Tenths of the Polariscope Reading	Per Cent Sucrose
0.1	0.02	0.1	0.02
0.2	0.05	0.2	0.05
0.3	0.07	0.3	0.07
0.4	0.10	0.4	0.10
0.5	0.12	0.5	0.12
0.6	0.15	0.6	0.15
0.7	0.17	0.7	0.17
0.8	0.20	0.8	0.19
0.9	0.22	0.9	0.22

Table V-A

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

Pol. Reading	Degrees Brix and Per Cent Sucrose																	Pol. Reading
	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	
40	9.96	9.94	9.92	9.90	9.88	9.86	9.84	9.82	9.80	9.78	9.76	9.74	9.72	9.70	9.68	9.66	9.64	40
41	10.20	10.18	10.17	10.15	10.12	10.10	10.08	10.06	10.04	10.02	10.00	9.98	9.96	9.94	9.92	9.90	9.88	41
42	10.45	10.43	10.42	10.40	10.37	10.35	10.33	10.31	10.29	10.26	10.24	10.22	10.20	10.18	10.16	10.14	10.12	42
43	10.70	10.68	10.67	10.65	10.62	10.60	10.58	10.56	10.53	10.51	10.49	10.47	10.44	10.42	10.41	10.38	10.36	43
44	10.95	10.93	10.91	10.89	10.86	10.85	10.83	10.81	10.78	10.76	10.74	10.72	10.69	10.67	10.65	10.63	10.60	44
45	11.20	11.18	11.16	11.14	11.11	11.09	11.07	11.05	11.02	11.00	10.98	10.96	10.93	10.91	10.89	10.87	10.85	45
46	—	11.43	11.41	11.39	11.36	11.34	11.32	11.29	11.27	11.25	11.23	11.20	11.18	11.16	11.14	11.11	11.08	46
47	—	11.67	11.66	11.63	11.61	11.59	11.56	11.54	11.51	11.49	11.47	11.44	11.42	11.40	11.37	11.35	11.33	47
48	—	—	11.90	11.89	11.86	11.84	11.81	11.79	11.76	11.74	11.72	11.69	11.66	11.64	11.62	11.59	11.56	48
49	—	—	12.15	12.13	12.10	12.08	12.05	12.03	12.00	11.98	11.96	11.93	11.90	11.88	11.86	11.83	11.80	49
50	—	—	—	12.38	12.35	12.33	12.30	12.28	12.25	12.23	12.20	12.18	12.15	12.13	12.10	12.08	12.05	50
51	—	—	—	12.63	12.60	12.57	12.54	12.52	12.49	12.47	12.44	12.42	12.39	12.37	12.34	12.32	12.29	51
52	—	—	—	—	12.85	12.82	12.79	12.77	12.74	12.71	12.69	12.67	12.63	12.62	12.58	12.56	12.53	52
53	—	—	—	—	13.09	13.07	13.04	13.01	12.99	12.96	12.93	12.91	12.87	12.86	12.83	12.80	12.77	53
54	—	—	—	—	—	13.32	13.29	13.26	13.24	13.20	13.18	13.15	13.12	13.11	13.07	13.04	13.01	54
55	—	—	—	—	—	13.56	13.53	13.50	13.48	13.44	13.42	13.39	13.36	13.34	13.31	13.28	13.25	55
56	—	—	—	—	—	—	13.78	13.75	13.73	13.69	13.66	13.64	13.61	13.58	13.55	13.52	13.50	56
57	—	—	—	—	—	—	14.02	13.99	13.97	13.93	13.90	13.88	13.85	13.82	13.79	13.76	13.74	57
58	—	—	—	—	—	—	—	14.24	14.21	14.18	14.15	14.12	14.09	14.07	14.04	14.01	13.98	58
59	—	—	—	—	—	—	—	14.48	14.45	14.42	14.39	14.36	14.33	14.31	14.28	14.25	14.22	59
60	—	—	—	—	—	—	—	—	14.70	14.67	14.64	14.61	14.58	14.55	14.52	14.49	14.46	60
61	—	—	—	—	—	—	—	—	14.95	14.91	14.88	14.85	14.82	14.79	14.76	14.73	14.70	61
62	—	—	—	—	—	—	—	—	—	15.16	15.13	15.10	15.07	15.04	15.00	14.97	14.94	62
63	—	—	—	—	—	—	—	—	—	15.40	15.37	15.34	15.31	15.28	15.24	15.21	15.18	63
64	—	—	—	—	—	—	—	—	—	15.65	15.62	15.59	15.56	15.53	15.49	15.46	15.43	64
65	—	—	—	—	—	—	—	—	—	—	15.86	15.83	15.80	15.77	15.73	15.70	15.67	65
66	—	—	—	—	—	—	—	—	—	—	16.10	16.07	16.04	16.01	15.97	15.94	15.91	66
67	—	—	—	—	—	—	—	—	—	—	—	16.31	16.28	16.25	16.21	16.18	16.15	67
68	—	—	—	—	—	—	—	—	—	—	—	—	16.52	16.49	16.46	19.43	16.39	68
69	—	—	—	—	—	—	—	—	—	—	—	—	16.77	16.73	16.70	16.67	16.63	69
70	—	—	—	—	—	—	—	—	—	—	—	—	17.01	16.98	16.94	16.91	16.87	70
71	—	—	—	—	—	—	—	—	—	—	—	—	—	17.22	17.18	17.15	17.11	71

Table V-A (Continued)

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

Pol.	Degrees Brix and Per Cent Sucrose																	Pol.
Reading	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	Reading
72	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17.39	17.35	72
73	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17.63	17.59	73
74	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17.87	17.83	74
75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18.11	18.08	75
76	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18.35	18.32	76

Degree Brix from 11.5 to 22.5	
Tenth of the polariscope Reading	Per Cent Sucrose
0.1	0.02
0.2	0.05
0.3	0.07
0.4	0.10
0.5	0.12
0.6	0.15
0.7	0.17
0.8	0.19
0.9	0.22

Table V-A (Continued)

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

Pol. Reading	Degree Brix and Per Cent Sucrose									Pol. Reading
	20.0	20.5	21.0	21.5	22.0	22.5	23.5	24.0	24.0	
40	9.62	9.60	9.58	9.56	9.54	9.52	9.50	9.48	9.46	40
41	9.86	9.84	9.82	9.80	9.78	9.76	9.74	9.72	9.70	41
42	10.10	10.08	10.06	10.04	10.02	10.00	9.98	9.96	9.94	42
43	10.34	10.32	10.30	10.28	10.26	10.24	10.22	10.20	10.18	43
44	10.58	10.56	10.54	10.52	10.49	10.47	10.46	10.44	10.41	44
45	10.82	10.80	10.78	10.76	10.73	10.71	10.69	10.67	10.64	45
46	11.06	11.04	11.02	11.00	10.97	10.95	10.93	10.90	10.88	46
47	11.30	11.28	11.26	11.24	11.21	11.19	11.17	11.14	11.12	47
48	11.54	11.52	11.50	11.48	11.45	11.43	11.41	11.38	11.36	48
49	11.78	11.76	11.74	11.72	11.69	11.67	11.65	11.62	11.60	49
50	12.03	12.00	11.98	11.95	11.93	11.90	11.88	11.85	11.83	50
51	12.27	12.24	12.22	12.19	12.17	12.14	12.12	12.09	12.07	51
52	12.51	12.48	12.46	12.43	12.41	12.38	12.35	12.33	12.30	52
53	12.75	12.72	12.70	12.67	12.65	12.62	12.59	12.57	12.53	53
54	12.98	12.96	12.94	12.91	12.89	12.86	12.83	12.80	12.77	54
55	13.22	13.20	13.17	13.15	13.12	13.09	13.06	13.04	13.01	55
56	13.47	13.44	13.41	13.39	13.36	13.33	13.30	13.28	13.24	56
57	13.71	13.68	13.65	13.63	13.60	13.57	13.54	13.52	13.48	57
58	13.95	13.92	13.89	13.87	13.54	13.81	13.77	13.75	13.72	58
59	14.19	14.16	14.13	14.11	14.08	14.05	14.01	13.98	13.96	59
60	14.43	14.40	14.37	14.34	14.31	14.28	14.25	14.22	14.19	60
61	14.67	14.64	14.61	14.58	14.55	14.52	14.49	14.46	14.42	61
62	14.91	14.88	14.85	14.82	14.79	14.76	14.73	14.69	14.66	62
63	15.15	15.12	15.09	15.06	15.03	14.99	14.96	14.93	14.90	63
64	15.39	15.36	15.33	15.30	15.27	15.24	15.20	15.17	15.14	64
65	15.63	15.60	15.57	15.54	15.51	15.48	15.44	15.41	15.38	65
66	15.87	15.84	15.81	15.78	15.74	15.71	15.68	15.64	15.61	66
67	16.11	16.08	16.05	16.02	15.98	15.95	15.92	15.88	15.85	67
68	16.35	16.32	16.29	16.26	16.22	16.19	16.16	16.12	16.09	68
69	16.59	16.56	16.53	16.50	16.46	16.43	16.39	16.35	16.33	69
70	16.84	16.80	16.77	16.73	16.70	16.66	16.63	16.59	16.56	70
71	17.08	17.04	17.00	16.97	16.93	19.89	16.86	16.83	16.79	71

Table V-A (Continued)

Schmitz's Table (Recalculated) For Sucrose for the use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions (Temperature 20 °C)

Pol. Reading	Degree Brix and Per Cent Sucrose									Pol. Reading
	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	
72	17.32	17.28	17.24	17.21	17.17	17.13	17.10	17.07	17.03	72
73	17.56	17.52	17.48	17.45	17.41	17.37	17.34	17.31	17.27	73
74	17.80	17.76	17.72	17.69	17.65	17.61	17.58	17.55	17.50	74
75	18.04	18.00	17.96	17.93	17.89	17.85	17.81	17.78	17.74	75
76	18.28	18.24	18.20	18.17	18.13	18.09	18.05	18.02	17.98	76
77	18.52	18.48	18.44	18.41	48.37	18.33	18.29	18.26	18.22	77
78	18.76	18.72	18.68	18.65	18.61	18.57	18.53	18.49	18.45	78
79	19.00	18.96	18.92	18.89	18.85	18.81	18.77	18.73	18.69	79
80	19.24	19.20	19.16	19.12	19.02	19.04	19.00	18.96	18.92	80
81	—	19.44	19.40	19.36	19.32	19.28	19.24	19.20	19.16	81
82	—	19.68	19.64	19.60	19.56	19.52	19.48	19.44	19.40	82
83	—	—	19.88	19.84	19.80	19.76	19.72	19.68	19.64	83
84	—	—	20.12	20.08	20.04	19.99	19.95	19.92	19.88	84
85	—	—	—	20.32	20.28	20.23	20.19	20.15	20.10	85

Degree Brix from 23 to 24

Tenths of the Polariscope Reading	Per Cent Sucrose	Tenths of the Polariscope Reading	Per Cent Sucrose
0.1	0.02	0.5	0.12
0.2	0.05	0.6	0.14
0.3	0.07	0.7	0.17
0.4	0.09	0.8	0.19
		0.9	0.21

Table V-B

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5 °C.

Pol. Reading	Degrees Brix and Per Cent Pol.													Pol. Reading
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	
1	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	1
2	—	0.52	0.52	0.52	0.52	0.52	0.52	0.51	0.51	0.51	0.51	0.51	0.51	2
3	—	0.78	0.78	0.78	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.76	3
4	—	—	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	4
5	—	—	1.30	1.30	1.29	1.29	1.29	1.29	1.28	1.28	1.28	1.28	1.27	5
6	—	—	—	1.56	1.55	1.55	1.55	1.54	1.54	1.54	1.53	1.53	1.53	6
7	—	—	—	1.81	1.81	1.81	1.80	1.80	1.80	1.79	1.79	1.79	1.79	7
8	—	—	—	—	2.07	2.07	2.06	2.06	2.05	2.05	2.05	2.04	2.04	8
9	—	—	—	—	2.33	2.32	2.32	2.31	2.31	2.31	2.30	2.30	2.29	9
10	—	—	—	—	—	2.58	2.58	2.57	2.57	2.56	2.56	2.55	2.55	10
11	—	—	—	—	—	2.84	2.83	2.83	2.82	2.82	2.81	2.81	2.80	11
12	—	—	—	—	—	—	3.09	3.09	3.08	3.07	3.07	3.06	3.06	12
13	—	—	—	—	—	—	3.35	3.34	3.34	3.33	3.32	3.32	3.31	13
14	—	—	—	—	—	—	—	3.60	3.59	3.59	3.58	3.57	3.57	14
15	—	—	—	—	—	—	—	3.86	3.85	3.84	3.84	3.83	3.82	15
16	—	—	—	—	—	—	—	—	4.11	4.10	4.09	4.08	4.07	16
17	—	—	—	—	—	—	—	—	4.36	4.36	4.35	4.34	4.33	17
18	—	—	—	—	—	—	—	—	—	4.61	4.60	4.59	4.48	18
19	—	—	—	—	—	—	—	—	—	4.87	4.86	4.85	4.84	19
20	—	—	—	—	—	—	—	—	—	—	5.11	5.10	5.09	20
21	—	—	—	—	—	—	—	—	—	—	5.37	5.36	5.35	21
22	—	—	—	—	—	—	—	—	—	—	—	5.61	5.60	22
23	—	—	—	—	—	—	—	—	—	—	—	5.87	5.86	23
24	—	—	—	—	—	—	—	—	—	—	—	—	6.11	24
25	—	—	—	—	—	—	—	—	—	—	—	—	6.37	25

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5 °C.

Pol. Reading	Degrees Brix and Per Cent Pol.													Pol. Reading
	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	
1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1
2	0.51	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	2
3	0.76	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.75	0.75	0.75	3
4	1.02	10.1	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4
5	1.27	1.27	1.27	1.26	1.26	1.26	1.26	1.25	1.25	1.25	1.25	1.24	1.24	5
6	1.53	1.52	1.52	1.52	1.51	1.51	1.51	1.50	1.50	1.50	1.50	1.49	1.49	6
7	1.78	1.78	1.77	1.77	1.77	1.76	1.76	1.75	1.75	1.75	1.74	1.74	1.74	7
8	2.03	2.03	2.03	2.02	2.02	2.01	2.01	2.01	2.00	2.00	1.99	1.99	1.99	8
9	2.29	2.28	2.28	2.27	2.27	2.27	2.26	2.26	2.25	2.25	2.24	2.24	2.23	9
10	2.54	2.54	2.53	2.53	2.52	2.52	2.51	2.51	2.50	2.50	2.49	2.49	2.48	10
11	2.80	2.79	2.79	2.78	2.77	2.77	2.76	2.76	2.75	2.75	2.74	2.74	2.73	11
12	3.05	3.04	3.04	3.03	3.03	3.02	3.01	3.01	3.00	3.00	2.99	2.98	2.98	12
13	3.30	3.30	3.29	3.28	3.28	3.27	3.27	3.26	3.25	3.25	3.24	3.23	3.23	13
14	3.56	3.55	3.54	3.54	3.53	3.52	3.52	3.51	3.50	3.50	3.49	3.48	3:48	14
15	3.81	3.81	3.80	3.79	3.78	3.78	3.77	3.76	3.75	3.75	3.74	3.73	3.72	15
16	4.07	4.06	4.05	4.04	4.04	4.03	4.02	4.01	4.00	4.00	3.99	3.98	3.97	16
17	4.32	4.31	4.30	4.30	4.29	4.28	4.27	4.26	4.25	4.25	4.24	4.23	4.22	17
18	4.58	4.57	4.56	4.55	4.54	4.53	4.52	4.51	4.50	4.49	4.49	4.48	4.47	18
19	4.83	4.82	4.81	4.80	4.79	4.78	4.77	4.76	4.75	4.74	4.74	4.73	4.72	19
20	5.08	5.07	5.06	5.05	5.04	5.03	5.02	5.01	5.00	4.99	4.98	4.97	4.96	20
21	5.34	5.33	5.32	5.31	5.30	5.29	5.28	5.26	5.25	5.24	5.23	5.22	5.21	21
22	5.59	5.58	5.57	5.56	5.55	5.54	5.53	5.52	5.50	5.49	5.48	5.47	5.46	22

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry Lead Method and in Polarizing Undiluted Solutions for Brix spindles standardised at 27.5 °C

Pol. Reading	Degrees Brix and Per Cent Pol.													Pol. Reading
	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	
23	5.85	5.83	5.82	5.81	5.80	5.79	5.78	5.77	5.75	5.74	5.73	5.72	5.71	23
24	6.10	6.09	6.08	6.06	6.05	6.04	6.03	6.02	6.00	5.99	5.98	5.97	5.96	24
25	6.35	6.34	6.33	6.32	6.30	6.29	6.28	6.27	6.26	6.24	6.23	6.22	6.21	25
26	6.61	6.60	6.58	6.57	6.56	6.54	6.53	6.52	6.51	6.49	6.48	6.47	6.45	26
27	6.86	6.85	6.84	6.82	6.81	6.80	6.78	6.77	6.75	6.74	6.73	6.72	6.70	27
28	_	7.10	7.09	7.08	7.06	7.05	7.03	7.02	7.01	6.99	6.98	6.96	6.95	28
29	_	7.36	7.34	7.33	7.31	7.30	7.28	7.27	7.26	7.24	7.23	7.21	7.20	29
30	_	_	7.60	7.58	7.57	7.55	7.54	7.52	7.51	7.49	7.48	7.46	7.45	30
31	_	_	7.85	7.83	7.82	7.80	7.79	7.77	7.76	7.74	7.73	7.71	7.69	31
32	_	_	_	8.09	8.07	8.05	8.04	8.02	8.01	7.99	7.97	7.96	7.94	32
33	_	_	_	8.34	8.32	8.31	8.29	8.27	8.26	8.24	8.22	8.21	8.19	33
34	_	_	_	_	8.57	8.56	8.54	8.53	8.51	8.49	8.47	8.46	8.44	34
35	_	_	_	_	8.83	8.81	8.79	8.77	8.76	8.74	8.72	8.70	8.69	35
36	_	_	_	_	_	9.06	9.04	9.03	9.01	8.99	8.97	8.95	8.94	36
37	_	_	_	_	_	9.31	9.29	9.28	9.26	9.24	9.22	9.20	9.18	37
38	_	_	_	_	_	_	9.55	9.53	9.51	9.49	9.47	9.45	9.43	38
39	_	_	_	_	_	_	9.80	9.78	9.76	9.74	9.72	9.70	9.68	39
40	_	_	_	_	_	_	_	10.02	10.01	9.99	9.97	9.95	9.93	40
41	_	_	_	_	_	_	_	10.28	10.26	10.24	10.22	10.20	10.18	41
42	_	_	_	_	_	_	_	_	10.51	10.49	10.47	10.45	10.43	42
43	_	_	_	_	_	_	_	_	10.76	10.74	10.72	10.69	10.67	43

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardised at 27.5 °C.

Pol. Reading	Degrees Brix and Per Cent Pol.													Pol. Reading
	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	
44	–	–	–	–	–	–	–	–	–	10.99	10.97	10.94	10.92	44
45	–	–	–	–	–	–	–	–	–	11.24	11.21	11.19	11.17	45
46	–	–	–	–	–	–	–	–	–	11.49	11.46	11.44	11.42	46
47	–	–	–	–	–	–	–	–	–	–	11.71	11.69	11.67	46
48	–	–	–	–	–	–	–	–	–	–	11.96	11.94	11.91	48
49	–	–	–	–	–	–	–	–	–	–	–	12.19	12.16	49
50	–	–	–	–	–	–	–	–	–	–	–	12.44	12.41	50
51	–	–	–	–	–	–	–	–	–	–	–	–	12.66	51
52	–	–	–	–	–	–	–	–	–	–	–	–	12.91	52

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5 °C.

Pol. Reading	Degrees Brix and Per Cent Pol.												Pol. Reading
	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	
10	2.48	2.47	2.47	2.46	2.46	2.45	2.45	2.44	2.44	2.43	2.43	2.42	10
11	2.72	2.72	2.71	2.71	2.70	2.70	2.69	2.69	2.68	2.68	2.67	2.67	11
12	2.97	2.97	2.96	2.95	2.95	2.94	2.94	2.93	2.93	2.92	2.91	2.91	12
13	3.22	3.21	3.21	3.20	3.19	3.19	3.18	3.18	3.17	3.16	3.16	3.15	13
14	3.47	3.46	3.45	3.45	3.44	3.43	3.43	3.42	3.41	3.41	3.40	3.39	14
15	3.72	3.71	3.70	3.69	3.69	3.68	3.67	3.66	3.66	3.65	3.64	3.63	15
16	3.96	3.96	3.95	3.94	3.93	3.92	3.92	3.91	3.90	3.89	3.88	3.88	16
17	4.21	4.20	4.19	4.19	4.18	4.17	4.16	4.15	4.14	4.14	4.13	4.12	17
18	4.46	4.45	4.44	4.43	4.42	4.41	4.41	4.40	4.39	4.38	4.37	4.36	18
19	4.71	4.70	4.69	4.68	4.67	4.66	4.65	4.64	4.63	4.62	4.61	4.60	19
20	4.95	4.94	4.93	4.92	4.91	4.90	4.90	4.89	4.88	4.87	4.86	4.85	20
21	5.20	5.19	5.18	5.17	5.16	5.15	5.14	5.13	5.12	5.11	5.10	5.09	21
22	5.45	5.44	5.43	5.42	5.41	5.40	5.38	5.37	5.36	5.35	5.34	5.33	22
23	5.70	5.69	5.67	5.66	5.65	5.64	5.63	5.62	5.61	5.60	5.58	5.57	23
24	5.95	5.93	5.92	5.91	5.90	5.89	5.87	5.86	5.85	5.84	5.83	5.81	24
25	6.19	6.18	6.17	6.16	6.14	6.13	6.12	6.11	6.09	6.08	6.07	6.06	25
26	6.44	6.43	6.42	6.40	6.39	6.38	6.36	6.35	6.34	6.32	6.31	6.30	26
27	6.69	6.68	6.66	6.65	6.63	6.62	6.61	6.59	6.58	6.57	6.55	6.54	27
28	6.94	6.92	6.91	6.89	6.88	6.87	6.85	6.84	6.83	6.81	6.80	6.78	28
29	7.18	7.17	7.16	7.14	7.13	7.11	7.10	7.08	7.07	7.05	7.04	7.03	29
30	7.43	7.42	7.40	7.39	7.37	7.36	7.34	7.33	7.31	7.30	7.28	7.27	30
31	7.68	7.66	7.65	7.63	7.62	7.60	7.59	7.57	7.56	7.54	7.53	7.51	31

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5°C.

Pol. Reading	Degrees Brix and Per Cent Pol.												Pol. Reading
	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	
32	7.93	7.91	7.90	7.88	7.86	7.85	7.83	7.82	7.80	7.78	7.77	7.75	32
33	8.17	8.16	8.14	8.13	8.11	8.09	8.08	8.06	8.04	8.03	8.01	8.00	33
34	8.42	8.41	8.39	8.37	8.36	8.34	8.32	8.30	8.29	8.27	8.25	8.24	34
35	8.67	8.65	8.64	8.62	8.60	8.58	8.57	8.55	8.53	8.51	8.50	8.48	35
36	8.92	8.90	8.88	8.86	8.85	8.83	8.81	8.79	8.78	8.76	8.74	8.72	36
37	9.17	9.15	9.13	9.11	9.09	9.07	9.06	9.04	9.02	9.00	8.98	8.96	37
38	9.41	9.39	9.38	9.36	9.34	9.32	9.30	9.28	9.26	9.24	9.23	9.21	38
39	9.66	9.64	9.62	9.60	9.58	9.56	9.55	9.53	9.51	9.49	9.47	9.45	39
40	9.91	9.89	9.87	9.85	9.83	9.81	9.79	9.77	9.75	9.73	9.71	9.69	40
41	10.16	10.14	10.12	10.10	10.08	10.06	10.03	10.01	9.99	9.97	9.95	9.93	41
42	10.40	10.38	10.36	10.34	10.32	10.30	10.28	10.26	10.24	10.22	10.20	10.18	42
43	10.65	10.63	10.61	10.59	10.57	10.55	10.52	10.50	10.48	10.46	10.44	10.42	43
44	10.90	10.88	10.86	10.83	10.81	10.79	10.77	10.75	10.73	10.70	10.68	10.66	44
45	11.15	11.13	11.10	11.08	11.06	11.04	11.01	11.99	11.97	10.95	10.92	10.90	45
46	11.40	11.37	11.35	11.33	11.30	11.28	11.26	11.24	11.21	11.19	11.17	11.14	46
47	11.64	11.62	11.60	11.57	11.55	11.53	11.50	11.48	11.46	11.43	11.41	11.39	47
48	11.89	11.87	11.84	11.82	11.80	11.77	11.75	11.72	11.70	11.68	11.65	11.63	48
49	12.14	12.11	12.09	12.07	12.04	12.02	11.99	11.97	11.94	11.92	11.90	11.87	49
50	12.39	13.36	12.34	12.31	12.29	12.26	12.24	12.21	12.19	12.16	12.14	12.11	50
51	12.63	12.61	12.58	12.56	12.53	12.51	12.48	12.46	12.43	12.41	12.38	12.36	51
52	12.88	12.86	12.83	12.80	12.78	12.75	12.73	12.70	12.68	12.65	12.62	12.60	52
53	13.13	13.10	13.08	13.05	13.02	13.00	12.97	12.95	12.92	12.89	12.87	12.84	53
54	13.38	13.35	13.32	13.30	13.27	13.24	13.22	13.19	13.16	13.14	13.11	13.08	54

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5 °C.

Pol. Reading	Degrees Brix and Per Cent Pol.												Pol. Reading
	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	
55	–	13.60	13.57	13.54	13.52	13.49	13.46	13.43	13.41	13.38	13.36	13.33	55
56	–	13.84	13.82	13.79	13.76	13.73	13.71	13.68	13.65	13.62	13.60	13.57	56
57	–	–	14.06	14.04	14.01	13.98	13.95	13.92	13.89	13.87	13.84	13.81	57
58	–	–	14.31	13.28	13.25	14.22	14.20	14.17	14.14	14.11	14.08	14.05	58
59	–	–	–	14.53	14.50	14.47	14.44	14.41	14.38	14.35	14.32	14.29	59
60	–	–	–	14.77	17.74	14.71	14.69	14.66	14.63	14.60	14.57	14.54	60
61	–	–	–	–	14.99	14.96	14.93	14.90	14.87	14.84	14.81	14.78	61
62	–	–	–	–	15.24	15.21	15.17	15.14	15.11	15.08	15.05	15.02	62
63	–	–	–	–	15.48	15.45	15.42	15.39	15.36	15.33	15.29	15.26	63
64	–	–	–	–	–	15.70	15.66	15.63	15.60	15.57	15.54	15.51	64
65	–	–	–	–	–	15.94	15.91	15.88	15.84	15.81	15.78	15.75	65
66	–	–	–	–	–	–	16.15	16.12	16.09	16.06	16.02	15.99	66
67	–	–	–	–	–	–	16.40	16.37	16.33	16.30	16.27	16.23	67
68	–	–	–	–	–	–	–	16.60	16.58	16.54	16.51	14.48	68
69	–	–	–	–	–	–	–	16.85	16.82	16.79	16.75	16.72	69
70	–	–	–	–	–	–	–	–	17.06	17.03	16.99	16.96	70
71	–	–	–	–	–	–	–	–	17.31	17.27	7.24	17.20	71
72	–	–	–	–	–	–	–	–	–	17.52	17.48	17.44	72
73	–	–	–	–	–	–	–	–	–	17.76	17.72	17.69	73
74	–	–	–	–	–	–	–	–	–	18.00	17.97	17.98	74
75	–	–	–	–	–	–	–	–	–	–	18.21	18.17	75
76	–	–	–	–	–	–	–	–	–	–	18.45	18.41	76
77	–	–	–	–	–	–	–	–	–	–	–	18.66	77
78	–	–	–	–	–	–	–	–	–	–	–	18.90	78

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5°C.

Pol. Reading	Degrees Brix and Per Cent Pol.										Pol. Reading
	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	
25	6.04	6.03	6.02	6.01	6.00	5.98	5.97	5.96	9.95	5.93	25
26	6.29	6.27	6.26	6.25	6.24	6.22	6.21	6.20	6.18	6.17	26
27	6.53	6.51	6.50	6.49	6.48	6.46	6.45	6.44	6.42	6.41	27
28	6.77	6.76	6.74	6.73	6.71	6.70	6.69	6.67	6.66	6.65	28
29	7.01	7.00	6.98	6.97	6.95	6.94	6.93	6.91	6.90	6.88	29
30	7.25	7.24	7.22	7.21	7.19	7.18	7.16	7.15	7.14	7.12	30
31	7.50	7.48	7.46	7.45	7.43	7.42	7.40	7.39	7.37	7.36	31
32	7.74	7.72	7.71	7.69	7.67	7.66	7.64	7.63	7.61	7.60	32
33	7.98	7.96	7.95	7.93	7.91	7.90	7.88	7.87	7.85	7.83	33
34	8.22	8.20	8.19	8.17	8.15	8.14	8.12	8.10	8.09	8.07	34
35	8.46	8.45	8.43	8.41	8.39	8.38	8.36	8.34	8.32	8.31	35
36	8.70	8.69	8.67	8.65	8.63	8.62	8.60	8.58	8.56	8.54	36
37	8.95	8.93	8.91	8.89	8.87	8.85	8.84	8.82	8.80	8.78	37
38	9.19	9.17	9.15	9.13	9.11	9.09	9.08	9.06	9.04	9.02	38
39	9.43	9.41	9.39	9.37	9.35	9.33	9.31	9.30	9.28	9.26	39
40	9.67	9.65	9.63	9.61	9.59	9.57	9.55	9.53	9.51	9.49	40
41	9.91	9.89	9.87	9.85	9.83	9.81	9.79	9.77	9.75	9.73	41
42	10.16	10.13	10.11	10.09	10.07	10.05	10.03	10.01	9.99	9.97	42
43	10.40	10.38	10.35	10.33	10.31	10.29	10.27	10.25	10.23	10.21	43
44	10.64	10.62	10.60	10.57	10.55	10.53	10.51	10.49	10.47	10.44	44
45	10.88	10.86	10.84	10.81	10.79	10.77	10.75	10.73	10.70	10.68	45
46	11.12	11.10	11.08	11.05	11.03	11.01	10.99	10.96	10.94	10.92	46

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5 °C.

Pol. Reading	Degrees Brix and Per Cent Pol.										Pol. Reading
	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	
47	11.36	11.34	11.32	11.29	11.27	11.25	11.23	11.20	11.18	11.16	47
48	11.61	11.58	11.56	11.53	11.51	11.49	11.46	11.44	11.42	11.39	48
49	11.85	11.82	11.80	11.78	11.75	11.73	11.70	11.68	11.65	11.63	49
50	12.09	12.06	12.04	12.02	11.99	11.97	11.94	11.92	11.89	11.87	50
51	12.33	12.31	12.28	12.26	12.23	12.21	12.18	12.16	12.13	12.11	51
52	12.57	12.55	12.52	12.50	12.47	12.44	12.42	12.39	12.37	12.34	52
53	12.81	12.79	12.76	12.74	12.71	12.68	12.66	12.63	12.61	12.58	53
54	13.06	13.03	13.00	12.98	12.95	12.92	12.90	12.87	12.84	12.82	54
55	13.30	13.27	13.24	13.22	13.19	13.16	13.14	13.11	13.08	13.05	55
56	13.54	13.51	13.48	13.46	13.43	13.40	13.37	13.35	13.32	13.29	56
57	13.78	13.75	13.73	13.70	13.67	13.64	13.61	13.59	13.56	13.53	57
58	14.02	13.99	13.97	13.94	13.91	13.88	13.85	13.82	13.80	13.77	58
59	14.27	14.24	14.21	14.18	14.15	14.12	14.09	14.06	14.03	14.00	59
60	14.51	14.48	14.45	14.42	14.39	14.36	14.33	14.30	14.27	14.24	60
61	14.75	14.72	17.69	14.66	14.63	14.60	14.57	14.54	14.51	14.48	61
62	14.99	14.96	14.93	14.90	14.87	14.84	14.81	14.78	14.75	14.72	62
63	15.23	15.20	15.17	15.14	15.11	15.08	15.05	15.02	14.98	14.95	63
64	15.47	15.44	15.41	15.38	15.35	15.32	15.29	15.25	15.22	15.19	64
65	15.72	15.68	15.65	15.62	15.59	15.56	15.52	15.49	15.46	15.43	65
66	15.96	15.93	15.89	15.86	15.83	15.80	15.76	15.73	15.70	15.67	66
67	16.20	16.17	16.13	16.10	16.07	16.03	16.00	15.97	15.94	15.90	67
68	16.44	16.41	16.37	16.34	16.31	16.27	16.24	16.21	16.17	16.14	68

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5°C.

Pol. Reading	Degrees Brix and Per Cent Pol.										Pol. Reading
	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	
69	16.68	16.65	15.62	16.58	16.55	16.51	16.48	16.45	16.41	16.38	69
70	16.93	16.89	16.86	16.82	16.79	16.75	16.72	16.68	16.65	16.61	70
71	17.17	17.13	17.10	17.06	17.03	16.99	16.96	16.92	16.89	16.85	71
72	17.41	17.37	17.34	17.30	17.27	17.23	77.20	17.16	17.13	17.09	72
73	17.65	17.61	17.58	17.54	17.51	17.47	14.43	17.40	17.36	17.33	73
74	17.89	17.86	17.82	17.78	17.75	17.71	17.67	17.64	17.60	17.56	74
75	18.13	18.10	18.06	18.02	17.99	17.95	17.91	17.88	17.84	17.80	75
76	18.38	18.34	18.30	18.26	18.23	18.19	18.15	18.11	18.08	18.04	76
77	18.62	18.58	18.54	18.50	18.47	18.43	18.39	18.35	18.31	18.28	77
78	18.86	18.82	18.78	18.74	18.71	18.67	18.63	18.59	18.55	18.51	78
79	19.10	19.06	19.02	18.98	18.95	18.91	18.87	18.83	18.79	18.75	79
80	19.34	19.30	19.26	19.22	19.19	19.15	19.11	19.07	19.03	18.99	80
81	_	19.54	19.50	19.46	19.43	19.39	19.35	19.31	19.27	19.24	81
82	_	19.79	19.75	19.71	19.66	19.62	19.58	19.54	19.50	19.46	82
83	_	_	19.99	19.95	19.90	19.86	19.82	19.78	19.74	19.70	83
84	_	_	20.23	20.19	20.14	20.10	20.06	20.02	19.98	19.94	84
85	_	_	20.47	20.43	20.38	20.34	20.30	20.26	20.22	20.18	85
86	_	_	_	20.67	20.62	20.58	20.54	20.50	20.45	20.41	86
87	_	_	_	20.91	20.86	20.82	20.78	20.74	20.69	20.65	87
88	_	_	_	_	21.10	21.06	21.02	20.97	20.93	20.89	88
89	_	_	_	_	21.34	21.30	21.26	21.21	21.17	21.12	89
90	_	_	_	_	_	21.54	21.49	21.45	21.41	21.36	90

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5 °C.

Pol. Reading	Degrees Brix and Per Cent Pol.										Pol. Reading
	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	
91	–	–	–	–	–	21.78	21.73	21.69	21.64	21.60	91
92	–	–	–	–	–	–	21.97	21.93	21.88	21.84	92
93	–	–	–	–	–	–	22.21	22.17	22.12	22.07	93
94	–	–	–	–	–	–	22.45	22.40	22.36	22.31	94
95	–	–	–	–	–	–	–	22.64	22.60	22.55	95
96	–	–	–	–	–	–	–	22.88	22.83	22.79	96
97	–	–	–	–	–	–	–	–	23.07	23.02	97
98	–	–	–	–	–	–	–	–	23.31	23.26	98
99	–	–	–	–	–	–	–	–	–	23.50	99
100	–	–	–	–	–	–	–	–	–	23.74	100
101	–	–	–	–	–	–	–	–	–	23.97	101

Table V-B (Continued)

Schmitz's Table for use in Horne's Dry lead method and in polarising undiluted solutions for Brix spindles standardized at 27.5°C.

Degrees Brix from 0.5 to 4.0	
Tenths of the Polarisecope Reading	Per Cent Pol.
0.1	0.03
0.2	0.05
0.3	0.08
0.4	0.10
0.5	0.13
0.6	0.16
0.7	0.18
0.8	0.21
0.9	0.23

Degrees Brix from 4.5 to 14.0	
Tenths of the Polariscope Reading	Per Cent Pol.
0.1	0.03
0.2	0.05
0.3	0.08
0.4	0.10
0.5	0.13
0.6	0.15
0.7	0.18
0.8	0.20
0.9	0.23

Degrees Brix from 14.5 to 20.0	
Tenths of the Polarisecope Reading	Per Cent Pol.
0.1	0.02
0.2	0.05
0.3	0.07
0.4	0.10
0.5	0.12
0.6	0.15
0.7	0.17
0.8	0.20
0.9	0.22

Degrees Brix from 20.5 to 24.0	
Tenths of the Polariscope Reading	Per Cent Pol.
0.1	0.02
0.2	0.05
0.3	0.07
0.4	0.10
0.5	0.12
0.6	0.14
0.7	0.17
0.8	0.19
0.9	0.21

Table VI

Specific Gravities of Common Acids and Alkalies.
Aqueous Solutions (From Int. Critical Tables, 1928)

Direct interpolation may be used for fractions of per cents

Percent Material by Weight	HCl	HNO_3	H_2SO_4	H_3PO_4	NaOH	KOH	NH_3
	20°/4°	20°/4°	20°/4°	20°/4°	20°/4°	15°/4°	20°/4°
1	1.0032	1.00364	1.0051	1.0038	1.0095	1.0083	0.9939
2	1.0082	1.00909	1.0118	1.0092	1.0207	1.0175	0.9895
3	..	1.01457	1.0184	..	1.0318	1.0267	..
4	1.0181	1.02008	1.0250	1.0200	1.0428	1.0359	0.9811
5	..	1.02563	1.0317	..	1.0538	1.0452	..
6	1.0279	1.03122	1.0385	1.0309	1.0648	1.0544	0.9730
7	..	1.0369	1.0453	..	1.0758	1.0637	
8	1.0376	1.0427	1.0522	1.0420	1.0869	1.0730	0.9651
9	..	1.0485	1.0591	..	1.0979	1.0824	..
10	1.0474	1.0543	1.0661	1.0532	1.1089	1.0918	0.9575
11	..	1.0602	1.0731	..	..	1.1013	..
12	1.0574	1.0661	1.0802	1.0647	1.1309	1.1108	0.9501
13	..	1.0721	1.0874	..	..	1.1203	..

Table VI (Continued)

Percent Material by Weight	HCl	HNO_3	H_2SO_4	H_3PO_4	NaOH	KOH	NH_3
	20°/4°	20°/4°	20°/4°	20°/4°	20°/4°	15°/4°	20°/4°
14	1.0675	1.0781	1.0947	1.0764	1.1530	1.1299	0.9430
15	..	1.0842	1.1020	..	..	1.1396	..
16	1.0776	1.0903	1.1094	1.0884	1.1751	1.1493	0.9362
17	..	1.0964	1.1168	..	..	1.1590	..
18	1.0878	1.1026	1.1243	1.1008	1.1972	1.1688	0.9295
19	..	1.1088	1.1318	..	..	1.1786	..
20	1.0980	1.1150	1.1394	1.1134	1.2191	1.1884	0.9229
21	..	1.1213	1.1471	..	..	1.1984	..
22	1.1083	1.1276	1.1548	1.1263	1.2411	1.2085	0.9164
23	..	1.1340	1.1626	..	..	1.2184	..
24	1.1187	1.1404	1.1704	1.1395	1.2629	1.2285	0.9101
25	..	1.1469	1.1783	..	..	1.2387	..
26	1.1290	1.1534	1.1862	1.1529	1.2848	1.2489	0.9040
27	..	1.1600	1.1942	..	..	1.2592	..
28	1.1392	1.1666	1.2023	1.1665	1.3064	1.2695	0.8980
29	..	1.1733	1.2104	..	..	1.2800	..
30	1.1493	1.1800	1.2185	1.1805	1.3279	1.2905	0.8920
31	..	1.1867	1.2267	..	..	1.3010	

Specific gravities of common acids and alkalies

Table VI (Continued)

Percent Material by Weight	HCl	HNO_3	H_2SO_4	H_3PO_4	NaOH	KOH	NH_3
	20°/4°	20°/4°	20°/4°	20°/4°	20°/4°	15°/4°	20°/4°
32	1.1593	1.1934	1.2349	..	1.3490	1.3117	..
33	..	1.2002	1.2432	..	..	1.3224	..
34	1.1691	1.2071	1.2515	..	1.3696	1.3331	..
35	..	1.2140	1.2599	1.216	..	1.3440	..
36	1.1789	1.2205	1.2684	..	1.3900	1.3549	..
37	..	1.2270	1.2769	..	..	1.3659	..
38	1.1885	1.2325	1.2855	..	1.4101	1.3769	..
39	..	1.2399	1.2941	..	..	1.3879	..
40	1.1980	1.2463	1.3028	1.254	1.4300	1.3991	..
45	..	1.2783	1.3476	1.293	..	1.4558	..
50	..	1.3100	1.3951	1.355	1.5253	..	..
55	..	1.3393	1.4453	1.379	..	..	..
60	..	1.3667	1.4983	1.426	..	..	..
70	..	1.4134	1.6105	..	..	..	..
80	..	1.4521	1.7272	..	..	..	..
90	..	1.4826	1.8144	..	..	..	..
100	..	1.5217	1.8305	..	..	..	..

Table VII-A*
Invert sugar table for 10 ml of Fehling's solution

ml of sugar solution required	Solutions containing besides invert sugar: No sucrose		1 g sucrose per 100 ml		5 g sucrose per 100 ml		10 g sucrose per 100 ml		25 g sucrose per 100 ml		ml of sugar solution required
	Invert sugar factor*	mg invert sugar per 100 ml	Invert sugar factor*	mg invert sugar per 100 ml	Invert sugar factor*	mg invert sugar per 100 ml	Invert sugar factor*	mg invert sugar per 100 ml	Invert sugar factor*	mg invert sugar per 100 ml	
15	50.5	336	49.9	333	47.6	317	46.1	307	43.4	289	15
16	50.6	316	50.0	312	47.6	297	46.1	288	43.4	217	16
17	50.7	298	50.1	295	47.6	280	46.1	271	43.4	255	17
18	50.8	282	50.1	278	47.6	264	46.1	256	43.3	240	18
19	50.8	267	50.2	264	47.6	250	46.1	243	43.3	277	19
20	50.9	254.5	50.2	251.0	47.6	238.0	46.1	230.5	43.2	216	20
21	51.0	242.5	50.2	239.0	47.6	226.7	46.1	219.5	43.2	206	21
22	51.0	231.8	50.3	228.2	47.6	216.4	46.1	209.5	43.1	196	22
23	51.1	222.2	50.3	218.7	47.6	207.0	46.1	200.4	43.0	187	23
24	51.2	213.3	50.3	209.8	47.6	198.3	46.1	192.1	42.9	179	24
25	51.2	204.8	50.4	201.6	47.6	190.4	46.0	184.0	42.8	171	25
26	51.3	197.4	50.4	193.8	47.6	183.1	46.0	176.9	42.8	164	26
27	51.4	190.4	50.4	186.7	47.6	176.4	46.0	170.4	42.7	158	27
28	51.4	183.7	50.5	180.2	47.7	170.3	46.0	164.3	42.7	152	28
29	51.5	177.6	50.5	174.1	47.7	164.5	46.0	158.6	42.6	147	29
30	51.5	171.7	50.5	168.3	47.7	159.0	46.0	153.3	42.5	142	30
31	51.6	166.3	50.6	163.1	47.7	153.9	45.9	148.1	42.5	137	31
32	51.6	161.2	50.6	158.1	47.7	149.1	45.9	143.4	42.4	132	32
33	51.7	156.6	50.6	153.3	47.7	144.5	45.9	139.1	42.3	128	33
34	51.7	152.2	50.6	148.9	47.7	140.3	45.8	134.9	42.2	124	34
35	51.8	147.9	50.7	144.7	47.7	136.3	45.8	130.9	42.2	121	35
36	51.8	143.9	50.7	140.7	47.7	132.5	45.8	127.1	42.1	117	36
37	51.9	140.2	50.7	137.0	47.7	128.9	45.7	123.5	42.0	114	37
38	51.9	136.6	50.7	133.5	47.7	125.5	45.7	120.3	42.0	111	38
39	52.2	133.3	50.8	130.2	47.7	122.3	45.7	117.1	41.9	107	39
40	52.0	130.1	50.8	127.0	47.7	119.2	45.6	114.1	41.8	104	40
41	52.1	127.1	50.8	123.9	47.7	116.3	45.6	111.2	41.8	102	41
42	52.1	124.2	50.8	121.0	47.7	113.5	45.6	108.5	41.7	99	42
43	52.2	121.4	50.8	118.2	47.7	110.9	45.5	105.8	41.6	97	43
44	52.2	118.7	50.9	115.6	47.7	108.4	45.5	103.4	41.5	94	44
45	52.3	116.1	50.9	113.1	47.7	106.0	45.4	101.0	41.4	92	45
46	52.3	113.7	50.9	110.6	47.7	103.7	45.4	98.7	41.4	90	46
47	52.4	111.4	50.9	108.2	47.7	101.5	45.3	96.4	41.3	88	47
48	52.4	109.2	50.9	106.0	47.7	99.4	45.3	94.3	41.2	86	48
49	52.5	107.1	51.0	104.0	47.7	97.4	45.2	92.3	41.1	84	49
50	52.5	105.1	51.0	102.0	47.7	95.4	45.2	90.4	41.0	82	50

* mg of invert sugar corresponding to 10 *ml* of Fehling's solution. (* From ICUMSA METHODS)

Table VII-B*

Invert sugar table for 25 ml of Fehling's solution

ml of sugar solution required	Solutions containing besides invert suger			
	No sucrose		1 g sucrose per 100 ml	
	Invert sugar factor *	mg Invert sugar per 100 ml	Invert sugar factor *	mg Invert sugar per 100 ml
15	123.6	824	122.6	817
16	123.6	772	122.7	767
17	123.6	727	122.7	721
18	123.7	687	122.7	682
19	123.7	651	122.8	646
20	123.8	619.0	122.8	614.0
21	123.8	589.0	122.8	584.8
22	123.9	563.2	122.9	558.2
23	123.9	538.7	122.9	534.0
24	124.0	516.7	122.9	512.1
25	124.0	496.0	123.0	492.0
26	124.1	477.3	123.0	473.1
27	124.1	459.7	123.0	455.6
28	124.2	443.6	123.1	439.6
29	124.2	428.3	123.1	424.4
30	124.3	414.3	123.1	410.4
31	124.3	401.0	123.2	397.4
32	124.4	388.7	123.2	385.0
33	124.4	377.0	123.2	373.4
34	124.5	366.2	123.3	362.6
35	124.5	355.8	123.3	352.3
36	124.6	346.1	123.3	342.5
37	124.6	336.8	123.4	333.5
38	124.7	328.1	123.4	324.7
39	124.7	319.7	123.4	316.4
40	124.8	311.9	123.4	308.6
41	124.8	304.9	123.5	301.2
42	124.9	297.3	123.5	294.1
43	124.9	290.5	123.5	287.3
44	125.0	284.1	123.6	280.9
45	125.0	277.9	123.6	274.7
46	125.1	272.0	123.6	268.7
47	125.1	266.3	123.7	263.1
48	125.2	260.8	123.7	257.7
49	125.2	255.5	123.7	252.5
50	125.3	250.6	138.8	247.6

* mg of invert sugar corresponding to 25 ml of Fehling's solution

(* From ICUMSA Methods-1977.)

Table VIII-A

Heat Value in Calorie (Major) per Kilogram of Bagasse burnt
(Stack Temperature 260 °C)

Per cent moisture in Bagasse	Theoretical Amount of Air	PER CENT EXCESS AIR			
		50	100	150	200
40	944.24	900.14	856.80	812.70	769.61
41	923.33	880.49	836.89	794.05	752.61
42	901.91	859.12	817.49	775.40	731.30
43	880.49	838.91	798.08	757.01	715.68
44	856.80	818.75	778.43	737.86	697.79
45	838.15	798.59	759.02	791.21	679.64
46	816.73	777.92	739.12	700.06	661.25
47	796.32	757.75	719.71	681.41	643.36
48	775.40	737.86	700.31	663.01	625.46
49	754.24	718.45	680.40	644.36	607.07
50	733.32	697.28	661.25	625.21	598.18
51	712.91	677.68	642.10	608.83	573.30
52	691.49	656.96	622.19	587.66	552.89
53	671.33	637.06	603.04	569.27	535.25
54	650.66	617.40	584.39	551.38	518.36

[Taken from Cane Sugar Hand Book by Spencer and Meade, Eighth Edition, 1945 and converted into metric units.]

Table VIII-B

Gross and Net Calorific Values of Bagasse for different values of sugar and moisture % bagasse.

I Gross Calorific Value = 4600 − 12 S − 46 x W
S = Sugar % bagasse
W = Moisture % bagasse.

W	S							
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
40	2748	2742	2736	2730	2724	2718	2712	2706
41	2702	2696	2690	2684	2678	2672	2666	2660
42	2656	2650	2644	2638	2632	2626	2620	2614
43	2610	2604	2598	2592	2586	2580	2574	2568
44	2564	2558	2552	2546	2540	2534	2528	2522
45	2518	2512	2506	2500	2494	2488	2482	2476
46	2472	2466	2460	2454	2448	2442	2436	2430
47	2426	2420	2414	2408	2402	2396	2390	2384
48	2380	2374	2368	2362	2356	2350	2344	2338
49	2334	2328	2322	2316	2310	2304	2298	2292
50	2288	2282	2276	2270	2264	2258	2252	2246
51	2242	2236	2230	2224	2218	2212	2206	2200
52	2196	2190	2184	2178	2172	2166	2160	2154

II Net Calorific Value = 4250 − 12S − 48.5 W.

W	S							
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
40	2298	2292	2286	2280	2274	2268	2262	2256
41	2250	2244	2238	2232	2226	2220	2214	2208
42	2201	2195	2189	2183	2177	2171	2165	2159
43	2152	2146	2140	2134	2128	2122	2116	2110
44	2104	2098	2092	2086	2080	2074	2068	2062
45	2056	2050	2044	2038	2032	2026	2020	2014
46	2007	2001	1995	1989	1983	1977	1971	1965
47	1958	1952	1946	1940	1934	1928	1922	1916
48	1910	1904	1898	1892	1886	1880	1874	1868
49	1862	1856	1850	1844	1838	1832	1826	1820
50	1813	1807	1801	1795	1789	1783	1777	1771
51	1764	1758	1752	1746	1740	1734	1728	1722
52	1716	1710	1704	1698	1692	1686	1680	1674

(Courtesy : Triveni Engg. Works Ltd., Khatauli)

Table IX

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution 20 °C and $27^1/_2$ °C.

Brix	20 °C	$27^1/_2$ °C	Brix	20 °C	$27^1/_2$ °C
1	2	3	1	2	3
0.0	.00000	.00000	.4	.06562	.06561
.2	.00200	.00200	.6	.06772	.06772
.4	.00401	.00401	.8	.06983	.06982
.6	.00601	.00601			
.8	.00802	.00802	7.0	.07149	.07193
			.2	.07405	.07405
1.0	.01004	.01004	.4	.07617	.07616
.2	.01206	.01206	.6	.07829	.07828
.4	.01408	.01408	.8	.08041	.08041
.6	.01610	.01610			
.8	.01813	.01813	8.0	.08254	.08253
			.2	.08467	.08466
2.0	.02016	.02016	.4	.08681	.08680
.2	.02219	.02219	.6	.08894	.08893
.4	.02422	.02422	.8	.09108	.09107
.6	.02626	.02626			
.8	.02831	.02831	9.0	.09323	.09322
			.2	.09537	.09536
3.0	.03035	.03035	.4	.09753	.09751
.2	.03240	.03240	.6	.09968	.09967
.4	.03445	.03445	.8	.10184	.10182
.6	.03651	.03651			
.8	.03857	.03857	10.0	.10400	.10398
			.2	.10616	.10615
4.0	.04063	.04063	.4	.10833	.10831
.2	.04269	.04269	.6	.11050	.11049
.4	.04476	.04476	.8	.11268	.11266
.6	.04683	.04683			
.8	.04891	.04891	11.0	.11485	.11484
			.2	.11704	.11702
5.0	.05098	.05098	.4	.11922	.11920
.2	.05306	.05306	.6	.12141	.12139
.4	.05515	.05514	.8	.12360	.12358
.6	.05724	.05723			
.8	.05933	.05932	12.0	.12580	.12578
			.2	.12800	.12797
6.0	.06142	.06142	.4	.13020	.13018
.2	.06352	.06351			

[Taken from Cane Sugar Hand Book by Spencer and Meade, Eighth Edition, 1945 and converted into metric units]

Table IX (Continued)

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution 20 °C and $27^1/_2$ °C.

Brix	20 °C	$27^1/_2$ °C	Brix	20 °C	$27^1/_2$ °C
1	2	3	1	2	3
.6	.13240	.13238	.4	.20956	.20950
.8	.13462	.13459	.6	.21190	.21183
			.8	.21423	.21416
13.0	.13683	.13680			
.2	.13904	.13902	20.0	.21657	.21651
.4	.14127	.14124	.2	.21892	.21885
.6	.14349	.14346	.4	.22127	.22120
.8	.14572	.14569	.6	.22362	.22355
			.8	.22598	.22590
14.0	.14795	.14792			
.2	.15018	.15015	21.0	.22834	.22826
.4	.15242	.15239	.2	.23070	.23063
.6	.15466	.15463	.4	.23307	.23299
.8	.15691	.15687	.6	.23545	.23536
			.8	.23782	.23774
15.0	.15916	.15912			
.2	.16141	.16137	22.0	.24020	.24012
.4	.16367	.16363	.2	.24259	.24250
.6	.16592	.16588	.4	.24498	.24489
.8	.16819	.16815	.6	.24737	.24728
			.8	.24976	.24967
16.0	.17045	.17041			
.2	.17273	.17268	23.0	.25216	.25207
.4	.17500	.17496	.2	.25457	.25447
.6	.17728	.17723	.4	.25697	.25688
.8	.17956	.17951	.6	.25939	.25929
			.8	.26180	.26170
17.0	.18185	.18180			
.2	.18413	.18408	24.0	.26422	.26412
.4	.18643	.18638	.2	.26664	.26654
.6	.18872	.18867	.4	.26907	.26896
.8	.19102	.19097	.6	.27150	.27139
			.8	.27394	.27383
18.0	.19333	.19327			
.2	.19564	.19558	25.0	.27638	.27638
.4	.19795	.19789	.2	.27882	.27870
.6	.20026	.20020	.4	.28127	.28115
.8	.20026	.20020	.6	.28372	.28360
			.8	.28618	.28605
19.0	.20490	.20484			
.2	.20723	.20717			

Table IX (Continued)

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution 20 °C and $27^1/_2$ °C.

Brix	20 °C	$27^1/_2$ °C	Brix	20 °C	$27^1/_2$ °C
1	2	3	1	2	3
26.0	.28864	.28851	.6	.37214	.37192
.2	.29110	.29097	.8	.37474	.37452
.4	.29357	.29344			
.6	.29604	.29591	33.0	.37735	.37713
.8	.29851	.29838	.2	.37996	.37973
			.4	.38257	.38235
27.0	.30100	.30086	.6	.38519	.38497
.2	.30348	.30334	.8	.38782	.38759
.4	.30597	.30583			
.6	.30846	.30832	34.0	.39045	.39021
.8	.31096	.31081	.2	.39308	.39284
			.4	.39572	.39548
28.0	.31346	.31331	.6	.39836	.39812
.2	.31596	.31581	.8	.40101	.40076
.4	.31847	.31832			
.6	.32098	.32083	35.0	.40366	.40341
.8	.32350	.32334	.2	.40631	.40606
			.4	.40898	.40872
29.0	.32602	.32586	.6	.41164	.40038
.2	.32855	.32838	.8	.41431	.41404
.4	.33108	.33091			
.6	.33361	.33344	36.0	.41698	.41671
.8	.33615	.33598	.2	.41966	.41939
			.4	.42234	.42207
30.0	.33869	.33852	.6	.42503	.42475
.2	.34124	.34106	.8	.42772	.42744
.4	.34379	.34361			
.6	.34635	.34616	37.0	.43042	.43013
.8	.34891	.34872	.2	.43312	.43283
			.4	.43582	.43554
31.0	.35147	.35128	.6	.43853	.43824
.2	.35404	.35385	.8	.44125	.44094
.4	.35661	.35642			
.6	.35919	.35899	38.0	.44397	.44366
.8	.36177	.36157	.2	.44669	.44638
			.4	.44942	.44911
32.0	.36436	.36415	.6	.45215	.45184
.2	.36694	.36674	.8	.45489	.45457
.4	.36954	.36933			

Table IX (Continued)

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution 20 °C and $27^1/_2$ °C.

Brix	20 °C	$27^1/_2$ °C	Brix	20 °C	$27^1/_2$ °C
1	2	3	1	2	3
39.0	.45763	.45731	.6	.55079	.55037
.2	.46038	.46005	.8	.55369	.55327
.4	.46313	.46280			
.6	.46589	.46555	46.0	.55660	.55618
.8	.46865	.46831	.2	.55952	.55909
			.4	.56244	.56201
40.0	.47141	.47107	.6	.56537	.56493
.2	.47418	.47384	.8	.56830	.56786
.4	.47696	.47661			
.6	.47974	.47938	47.0	.57123	.57079
.8	.48252	.48217	.2	.57417	.57373
			.4	.57712	.57667
41.0	.48531	.48495	.6	.58007	.57962
.2	.48810	.48774	.8	.58302	.58257
.4	.49090	.49054			
.6	.49370	.49334	48.0	.58598	.58553
.8	.49651	.49615	.2	.58895	.58849
			.4	.59192	.59146
42.0	.49933	.49896	.6	.59489	.59443
.2	.50215	.50177	.8	.59788	.59741
.4	.50497	.50459			
.6	.50780	.50742	49.0	.60086	.60039
.8	.51063	.51024	.2	.60386	.60338
			.4	.60685	.60638
43.0	.51346	.51308	.6	.60985	.60938
.2	.51630	.51592	.8	.61286	.61238
.4	.51915	.51876			
.6	.52201	.52161	50.0	.61587	.61539
.8	.52486	.52446	.2	.61889	.61840
			.4	.62191	.62142
44.0	.52772	.52732	.6	.62494	.62444
.2	.53059	.53018	.8	.62797	.62747
.4	.53346	.53305			
.6	.53633	.53593	51.0	.63101	.63061
.8	.53921	.53881	.2	.63405	.63355
			.4	.63710	.63659
45.0	.54210	.54169	.6	.64015	.63964
.2	.54499	.54457	.8	.64321	.64270
.4	.54789	.54747			

Table IX (Continued)

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution
20 °C and 27 1/2 °C.

Brix	20 °C	27 1/2 °C	Brix	20 °C	27 1/2 °C
1	2	3	1	2	3
52.0	.64628	.64576	.6	.75038	.74976
.2	.64934	.64882	.8	.75363	.75300
.4	.65242	.65189			
.6	.65550	.65497	59.0	.75689	.75625
.8	.65858	.65805	.2	.76015	.75951
			.4	.76341	.76277
53.0	.66167	.66114	.6	.76668	.76604
.2	.66477	.66423	.8	.76995	.76931
.4	.66787	.66733			
.6	.67098	.67043	60.0	.77324	.77258
.8	.67409	.67354	.2	.77653	.77587
			.4	.77982	.77916
54.0	.67720	.67665	.6	.78312	.78246
.2	.68032	.67977	.8	.78642	.78575
.4	.68345	.68289			
.6	.68658	.68602	61.0	.78973	.78906
.8	.68972	.68915	.2	.79305	.79237
			.4	.79636	.79569
55.0	.69287	.69230	.6	.79969	.79901
.2	.69602	.69544	.8	.80302	.80234
.4	.69917	.69859			
.6	.70233	.70175	62.0	.80637	.80568
.8	.70550	.70491	.2	.80971	.80902
			.4	.81306	.81237
56.0	.70867	.70808	.6	.81642	.81572
.2	.71185	.71125	.8	.81977	.81908
.4	.71503	.71443			
.6	.71821	.71761	63.0	.82314	.82244
.8	.72141	.72080	.2	.82652	.82581
			.4	.82989	.82918
57.0	.72460	.72400	.6	.83328	.83257
.2	.72781	.72720	.8	.83667	.83595
.4	.73102	.73041			
.6	.73423	.73362	64.0	.84006	.83934
.8	.73745	.73683	.2	.84347	.84275
			.4	.84687	.84615
58.0	.74068	.74006	.6	.85028	.84965
.2	.74391	.74328	.8	.85371	.85298
.4	.74715	.74652			

Table IX (Continued)

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution 20 °C and $27^1/_2$ °C.

Brix	20 °C	$27^1/_2$ °C	Brix	20 °C	$27^1/_2$ °C
1	2	3	1	2	3
65.0	.85713	.85639	.6	.97350	.97266
.2	.86056	.85983	.8	.97713	.97629
.4	.86400	.86326			
.6	.86744	.86670	72.0	.98077	.97991
.8	.87089	.87014	.2	.98442	.98355
			.4	.98806	.98720
66.0	.87434	.87359	.6	.99172	.99035
.2	.87781	.87705	.8	.99538	.99451
.4	.88127	.88052			
.6	.88474	.88398	73.0	.99905	.99817
.8	.88822	.88746	.2	1.00272	1.00184
			.4	1.00639	1.00552
67.0	.89170	.89093	.6	1.01009	1.00920
.2	.89520	.89443	.8	1.01378	1.01289
.4	.89869	.89792			
.6	.90219	.90142	74.0	1.01747	1.01658
.8	.90570	.90492	.2	1.02118	1.02028
			.4	1.02489	1.02399
68.0	.90291	.90843	.6	1.02861	1.02770
.2	.91273	.91195	.8	1.03233	1.03141
.4	.91627	.91547			
.6	.91980	.91900	75.0	1.03606	1.03515
.8	.92333	.92253	.2	1.03979	1.03888
			.4	1.04354	1.04262
69.0	.92688	.92607	.6	1.04729	1.04637
.2	.93043	.92962	.8	1.05104	1.05012
.4	.93399	.93317			
.6	.93755	.93673	76.0	1.05480	1.05388
.8	.94111	.94030	.2	1.05857	1.05764
			.4	1.06234	1.06141
70.0	.94469	.94384	.6	1.06612	1.06518
.2	.94827	.94745	.8	1.06991	1.06896
.4	.95186	.95103			
.6	.95545	.95462	77.0	1.07370	1.07276
.8	.95905	.95821	.2	1.07750	1.07655
			.4	1.08131	1.08036
71.0	.96265	.96182	.6	1.08512	1.08417
.2	.96626	.96542	.8	1.08894	1.08798
.4	.96988	.96904			
			78.0	1.09276	1.09180

Table IX (Continued)

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution 20 °C and $27^1/_2$ °C.

Brix	20 °C	$27^1/_2$ °C	Brix	20 °C	$27^1/_2$ °C
1	2	3	1	2	3
78.2	1.09660	1.09563	.8	1.22670	1.22561
.4	1.10043	1.09947			
.6	1.10427	1.10331	85.0	1.23075	1.22966
.8	1.10813	1.10715	.2	1.23481	1.23372
			.4	1.23888	1.23779
79.0	1.11199	1.11100	.6	1.24295	1.24186
.2	1.11585	1.11487	.8	1.24704	1.24594
.4	1.11972	1.11873			
.6	1.12359	1.12261	86.0	1.25113	1.25002
.8	1.12748	1.12648	.2	1.25523	1.25412
			.4	1.25932	1.25822
80.0	1.13137	1.13037	.6	1.26343	1.26232
.2	1.13526	1.13426	.8	1.26755	1.26643
.4	1.13917	1.13816			
.6	1.14308	1.14207	87.0	1.27168	1.28055
.8	1.14700	1.14598	.2	1.27581	1.27467
			.4	1.27994	1.27881
81.0	1.15091	1.14989	.6	1.28408	1.28295
.2	1.15484	1.15382	.8	1.12884	1.28710
.4	1.15878	1.15776			
.6	1.16272	1.16170	88.0	1.29239	1.29124
.8	1.16667	1.16564	.2	1.29656	1.29541
			.4	1.30073	1.29958
82.0	1.17062	1.16959	.6	1.30490	1.30375
.2	1.17459	1.17355	.8	1.30909	1.30793
.4	1.17856	1.17751			
.6	1.18253	1.18149	89.0	1.31328	1.31211
.8	1.18651	1.18546	.2	1.31748	1.31631
			.4	1.32168	1.32051
83.0	1.19050	1.18945	.6	1.32589	1.32472
.2	1.19449	1.19344	.8	1.33011	1.32893
.4	1.19850	1.19744			
.6	1.20251	1.20144	90.0	1.33433	1.33315
.8	1.20651	1.20545	.2	1.33857	1.33739
			.4	1.34280	1.34162
84.0	1.21054	1.20947	.6	1.34705	1.34586
.2	1.21458	1.21349	.8	1.35130	1.35011
.4	1.21861	1.21753			
.6	1.22265	1.22156	91.0	1.35556	1.35436

Table IX (Continued)

Weight of Solids (Brix) in Kilograms per litre of Sugar Solution 20 °C and $27^1/_2$ °C.

Brix	20 °C	$27^1/_2$ °C	Brix	20 °C	$27^1/_2$ °C
1	2	3	1	2	3
91.2	1.35983	1.35863	.8	1.45990	1.45861
.4	1.36411	1.36290			
.6	1.36838	1.36718	96.0	1.46434	1.46305
.8	1.37268	1.37146	.2	1.46878	1.46749
			.4	1.47322	1.47193
92.0	1.37697	1.37575	.6	1.47768	1.47639
.2	1.38127	1.38005	.8	1.48214	1.48085
.4	1.38557	1.38436			
.6	1.38990	1.38867	97.0	1.48662	1.48531
.8	1.39422	1.39299	.2	1.49110	1.48979
			.4	1.49559	1.49427
93.0	1.39854	1.39732	.6	1.50007	1.49877
.2	1.40288	1.40164	.8	1.50457	1.50326
.4	1.40723	1.40599			
.6	1.41158	1.41034	98.0	1.50908	1.50776
.8	1.41593	1.41469	.2	1.51360	1.51227
			.4	1.51812	1.51680
94.0	1.42030	1.41904	.6	1.52264	1.52132
.2	1.42467	1.42342	.8	1.52718	1.52585
.4	1.42905	1.42779			
.6	1.43344	1.43218	99.0	1.53172	1.53038
.8	1.43783	1.43656	.2	1.53627	1.53493
			.4	1.54083	1.53949
95.0	1.44223	1.44096	.6	1.54539	1.54405
.2	1.44664	1.44536	.8	1.54996	1.54862
.4	1.45105	1.44977			
.6	1.45547	1.45419	100.0	1.55454	1.55319

Table X

Amount of CaO in milk of Lime of Various Densities at 15 °C. (From Blatner's Table)

Degree Brix	Degree Beaume	Weight of one litre, Milk of Lime, Grams	CaO per Litre, Grams.	Per Cent CaO
1.8	1	1007	7.5	0.745
3.6	2	1014	16.5	1.64
5.4	3	1022	26.0	2.54
7.2	4	1029	36.0	3.50
9.0	5	1037	46.0	4.43
10.8	6	1045	56.0	5.36
12.6	7	1052	65.0	6.18
14.4	8	1060	75.0	7.08
16.2	9	1067	84.0	7.87
18.0	10	1075	94.0	8.74
19.8	11	1083	104.0	9.60
21.7	12	1091	115.0	10.54
23.5	13	1100	126.0	11.45
25.3	14	1108	137.0	12.35
27.2	15	1116	148.0	13.26
29.0	16	1125	159.0	14.13
30.8	17	1134	170.0	15.00
32.7	18	1142	181.0	15.85
34.6	19	1152	193.0	16.75
36.4	20	1162	206.0	17.72
38.3	21	1171	218.0	18.61
40.1	22	1180	229.0	19.40
42.0	23	1190	242.0	20.34
43.9	24	1200	255.0	21.25
45.8	25	1210	268.0	22.15
47.7	26	1220	281.0	23.03
49.6	27	1231	295.0	23.96
51.5	28	1241	309.0	24.90
53.5	29	1252	324.0	25.87
55.4	30	1263	339.0	26.74

Table XI-A

Properties of Dry Saturated Steam (Metric Units)

t = temperature, in°C
p = absolute pressure of the vapour, in kg/cm²
p' = gauge pressure of the vapour, in kg/cm²
d = density of water at t°C, in kg/dm³
q = sensible heat to raise 1 kg of water from 0 to t°C, in kcal/kg
r = latent heat of vaporisation of water at t°C, in kcal/g
λ = $q + r$ = total heat of 1 kg of water at t°C
$\bar{\omega}$ = density of vapour at t°C, in kg/m³
v = specific volume of vapour at t°C, in m³/kg

t	p	d	q	r	λ	$\bar{\omega}$	v
0	0.00623	0.99987	0	597.2	597.2	0.00485	206.3
5	0.00889	0.99999	5	594.4	599.4	0.00680	147.2
10	0.01251	0.99973	10	591.6	601.6	0.00940	106.4
15	0.01738	0.99913	15	588.8	603.8	0.01282	77.99
16	0.01853	0.99897	16	588.3	604.3	0.01363	73.39
17	0.01975	0.99880	17	587.7	604.7	0.01447	69.10
18	0.02103	0.99862	18	587.1	605.1	0.01536	65.10
19	0.02239	0.99843	19	586.6	605.6	0.01630	61.35
20	0.02383	0.99823	20	586	606	0.01729	57.84
21	0.02534	0.99802	21	585.5	606.5	0.01833	54.56
22	0.02694	0.99780	22	584.9	606.9	0.01942	51.49
23	0.02863	0.99756	23	584.3	607.3	0.02056	48.63
24	0.03041	0.99732	24	583.8	607.8	0.02177	45.94
25	0.03229	0.99707	25	583.2	608.2	0.02304	43.41
26	0.03426	0.99681	26	582.6	608.6	0.02437	41.04
27	0.03634	0.99654	27	582.1	609.1	0.02576	38.82
28	0.03853	0.99626	28	581.5	609.5	0.02723	36.73
29	0.04083	0.99597	29	581	610	0.02876	34.77
30	0.04325	0.99567	30	580.4	610.4	0.03036	32.93
31	0.04580	0.99537	31	579.8	610.8	0.03204	31.20
32	0.04847	0.99505	32	579.3	611.3	0.03380	29.58
33	0.05128	0.99463	33	578.7	611.7	0.03565	28.05
34	0.05423	0.99440	34	578.1	612.1	0.03758	26.61
35	0.05733	0.99406	35	577.5	612.5	0.03960	25.25
36	0.06057	0.99371	36	577	613	0.04171	23.97
37	0.06398	0.99336	37	576.4	613.4	0.04392	22.77
38	0.06755	0.99299	38	575.9	613.9	0.04622	21.63
39	0.07129	0.99262	39	575.3	614.3	0.04863	20.56
40	0.07520	0.99224	40	574.7	614.7	0.05114	19.55
41	0.07930	0.99186	41	574.2	615.2	0.05377	18.60
42	0.08360	0.99147	42	573.6	615.6	0.05650	17.70
43	0.08809	0.99107	43	573	616	0.05935	16.85
44	0.09279	0.99066	44	572.4	616.4	0.06233	16.04
45	0.09771	0.99024	45	571.8	616.8	0.06544	16.28
46	0.10284	0.98982	46	571.2	617.2	0.06867	14.56
47	0.10821	0.98940	47	570.7	617.7	0.07203	13.88
48	0.11382	0.98896	48	570.1	618.1	0.07553	13.24
49	0.11967	0.98852	49	569.5	618.5	0.07918	12.63
50	0.12578	0.98807	50	569	619	0.08298	12.05

(* From : 'Handbook of Cane Sugar Engineering' by E Hugot III Edition 1986.

Table XI-A (Continued)

t	p	d	q	r	λ	$\bar{\omega}$	ν
51	0.1322	0.98762	50.9	568.4	619.3	0.0869	11.50
52	0.1388	0.98715	51.9	567.8	619.7	0.0910	10.98
53	0.1457	0.98669	52.9	567.3	620.2	0.0953	10.49
54	0.1530	0.98621	53.9	566.7	620.6	0.0997	10.02
55	0.1605	0.98573	54.9	566.1	621	0.1043	9.584
56	0.1684	0.98524	55.9	565.6	621.5	0.1091	9.164
57	0.1765	0.98478	56.9	565	621.9	0.1141	8.764
58	0.1850	0.98425	57.9	564.4	622.3	0.1193	8.385
59	0.1939	0.98375	58.9	563.8	622.7	0.1247	8.025
60	0.2031	0.98324	59.9	563.3	623.2	0.1302	7.682
61	0.2127	0.98272	60.9	562.7	623.6	0.1359	7.356
62	0.2227	0.98220	61.9	562.1	624	0.1419	7.046
63	0.2330	0.98167	62.9	561.5	624.4	0.1481	6.752
64	0.2438	0.98113	63.9	560.9	624.8	0.1545	6.473
65	0.2550	0.98059	64.9	560.3	625.2	0.1611	6.206
66	0.2666	0.98005	65.9	559.7	625.6	0.1680	5.951
67	0.2787	0.97950	66.9	559.1	626	0.1752	5.709
68	0.2912	0.97894	67.9	558.5	626.4	0.1826	5.478
69	0.3024	0.97838	68.9	558	626.9	0.1902	5.258
70	0.3177	0.97781	69.9	557.4	627.3	0.1981	5.049
71	0.3317	0.97723	70.9	556.8	627.7	0.2062	4.849
72	0.3463	0.97666	71.9	556.2	628.1	0.2146	4.658
73	0.3613	0.97607	72.9	555.6	628.5	0.2234	4.476
74	0.3769	0.97548	73.9	555	628.9	0.2324	4.302
75	0.3931	0.97489	74.9	554.4	629.3	0.2418	4.136
76	0.4098	0.97429	75.9	553.8	629.7	0.2514	3.977
77	0.4272	0.97368	76.9	553.2	630.1	0.2614	3.826
78	0.4451	0.97307	77.9	552.6	630.5	0.2717	3.681
79	0.4637	0.97245	78.9	552	630.9	0.2823	3.543
80	0.4829	0.97183	80	551.3	631.3	0.2933	3.410
81	0.5028	0.97121	81	550.7	631.7	0.3046	3.283
82	0.5234	0.97057	82	550.1	632.1	0.3162	3.162
83	0.5447	0.96994	83	549.5	632.5	0.3282	3.047
84	0.5667	0.96930	84	548.8	632.8	0.3406	2.936
85	0.5894	0.96865	85	548.2	633.2	0.3534	2.830
86	0.6129	0.96800	86	547.6	633.6	0.3666	2.728
87	0.6372	0.96734	87	547	634	0.3802	2.630
88	0.6623	0.96668	88	546.4	634.4	0.3942	2.537
89	0.6882	0.96601	89	545.7	634.7	0.4086	2.447
90	0.7149	0.96534	90	545.1	635.1	0.4235	2.361
91	0.7425	0.96467	91	544.5	635.5	0.4388	2.279
92	0.7710	0.96399	92	534.9	635.9	0.4545	2.200
93	0.8004	0.96330	93	543.3	636.3	0.4707	2.124
94	0.8307	0.96261	94	542.7	636.7	0.4873	2.051
95	0.8619	0.96192	95	542	637	0.5045	1.981
96	0.8942	0.96122	96	541.4	637.4	0.5221	1.914
97	0.9274	0.96051	97	540.8	637.8	0.5402	1.851
98	0.9616	0.95981	98	540.2	638.2	0.5588	1.789
99	0.9969	0.95909	99	539.5	638.5	0.5780	1.730
100	1.0332	0.95838	100	538.9	638.9	0.5977	1.673

Table XI-A (Continued)

t	p	p'	q	r	λ	$\bar{\omega}$	v
101	1.0707	0.0375	101	538.3	639.3	0.6179	1.618
102	1.1092	0.0760	102	537.6	639.6	0.6387	1.565
103	1.1489	0.1157	103.1	536.9	640	0.6601	1.515
104	1.1898	0.1566	104.1	536.2	640.3	0.6820	1.466
105	1.2318	0.1986	105.1	535.6	640.7	0.7045	1.419
106	1.2751	0.2419	106.1	535	641.1	0.7276	1.374
107	1.3196	0.2864	107.1	534.3	641.4	0.7514	1.331
108	1.3654	0.3322	108.1	533.6	641.7	0.7758	1.289
109	1.4125	0.3793	109.1	533	642.1	0.8008	1.249
110	1.4609	0.4277	110.1	532.4	642.5	0.8265	1.210
111	1.5106	0.4774	111.1	531.8	642.9	0.8528	1.173
112	1.5618	0.5286	112.1	531.1	643.2	0.8798	1.137
113	1.6144	0.5812	113.2	530.4	643.6	0.9075	1.102
114	1.6684	0.6352	114.2	529.7	643.9	0.9359	1.068
115	1.7239	0.6907	115.2	529.1	644.3	0.9650	1.036
116	1.7809	0.7477	116.2	528.4	644.6	0.9947	1.005
117	1.8394	0.8062	117.2	527.8	645	1.026	0.9752
118	1.8995	0.8663	118.2	527.1	645.3	0.057	0.9462
119	1.9612	0.9280	119.2	526.4	645.6	1.089	0.9183
120	2.0245	0.9913	120.3	525.7	646	1.122	0.8914
121	2.0895	1.0563	121.3	525.1	646.4	1.156	0.8655
122	2.1561	1.1229	122.3	524.4	646.7	1.190	0.8404
123	2.2245	1.1913	123.3	523.7	647	1.225	0.8161
124	2.2947	1.2615	124.3	523.1	647.4	1.262	0.7927
125	2.3666	1.3334	125.3	522.4	647.7	1.299	0.7701
126	2.4404	1.4072	126.4	521.6	648	1.337	0.7482
127	2.5160	1.4828	127.4	520.9	648.3	1.376	0.7271
128	2.5935	1.5603	128.4	520.3	648.7	1.415	0.7068
129	2.6730	1.6398	129.4	519.6	649	1.455	0.6871
130	2.7544	1.7212	130.4	518.9	649.3	1.496	0.6680
131	2.8378	1.8046	131.4	518.2	649.6	1.539	0.6496
132	2.9233	1.8901	132.5	517.4	649.9	1.583	0.6318
133	3.011	1.978	133.5	516.7	650.2	1.628	0.6146
134	3.101	2.068	134.5	516	650.5	1.673	0.5979
135	3.192	2.159	135.5	515.3	650.8	1.719	0.5817
136	3.286	2.253	136.6	514.6	651.2	1.767	0.5661
137	3.382	2.349	137.6	513.9	651.5	1.815	0.5510
138	3.481	2.448	138.6	513.3	651.9	1.864	0.5363
139	3.582	2.549	139.6	512.6	652.2	1.915	0.5221
140	3.685	2.652	140.6	511.9	652.5	1.967	0.5084
141	3.790	2.757	141.7	511.1	652.8	2.020	0.4951
142	3.898	2.865	142.7	510.4	653.1	2.074	0.4823
143	4.009	2.976	143.7	509.7	653.4	2.129	0.4698
144	4.122	3.089	144.8	508.9	653.7	2.185	0.4577
145	4.237	3.204	145.8	508.2	654	2.243	0.4459
146	4.355	3.322	146.8	507.5	654.3	2.302	0.4345
147	4.476	3.443	147.8	506.8	654.6	2.362	0.4235
148	4.559	3.566	148.9	506	654.9	2.423	0.4128
149	4.725	3.692	149.9	505.3	655.2	2.485	0.4024
150	4.854	3.821	150.9	504.6	655.5	2.548	0.3924

Table XI-A (Continued)

p	p'	t	q	r	λ	$\bar{\omega}$	ν
5	3.967	151.11	152.1	503.7	655.8	2.621	0.3816
5.5	4.467	154.71	155.8	501.1	656.9	2.867	0.3488
6	4.967	158.08	159.3	498.5	657.8	3.112	0.3213
6.5	5.467	161.21	162.5	496.1	658.6	3.356	0.2980
7	5.967	164.17	165.6	493.8	659.4	3.600	0.2778
7.5	6.467	166.96	168.5	491.6	660.1	3.842	0.2603
8	6.967	169.61	171.3	489.5	660.8	4.085	0.2448
8.5	7.467	172.12	173.9	487.5	661.4	4.327	0.2311
9	7.967	174.53	176.4	485.6	662	4.568	0.2189
9.5	8.467	176.83	178.9	483.6	662.5	4.809	0.2080
10	8.967	179.04	181.2	481.8	663	5.049	0.1981
10.5	9.467	181.16	183.4	480.1	663.5	5.290	0.1891
11	9.967	183.20	185.6	478.3	663.9	5.530	0.1808
11.5	10.467	185.17	187.7	476.6	664.3	5.770	0.1733
12	10.967	187.08	189.7	475	664.7	6.010	0.1664
12.5	11.467	188.92	191.6	473.5	665.1	6.249	0.1600
13	11.967	190.71	193.5	471.9	665.4	6.488	0.1541
13.5	12.467	192.45	195.3	470.4	665.7	6.728	0.1486
14	12.967	194.13	197.1	468.9	666	6.967	0.1435
14.5	13.467	195.77	198.9	467.4	666.3	7.207	0.1388
15	13.967	197.36	200.6	466	666.6	7.446	0.1343
16	14.967	200.43	203.9	463.2	667.1	7.925	0.1262
17	15.967	203.35	207.1	460.4	667.5	8.405	0.1190
18	16.967	206.14	210.1	457.8	667.9	8.886	0.1126
19	17.967	208.81	213	455.2	668.2	9.366	0.1068
20	18.967	211.38	215.8	452.7	668.5	9.846	0.1016
21	19.967	213.85	218.5	450.2	668.7	10.33	0.09682
22	20.967	216.23	221.2	447.7	668.9	10.81	0.09251
23	21.967	218.53	223.6	445.5	669.1	11.29	0.08856
24	22.967	220.75	226.1	443.2	669.3	11.78	0.08492
25	23.967	222.90	228.5	440.9	669.4	12.26	0.08157
26	24.967	224.99	230.8	438.7	669.5	12.75	0.07846
27	25.967	227.01	233	436.6	669.6	13.23	0.07557
28	26.967	228.98	235.2	434.4	669.6	13.72	0.07288
29	27.967	230.89	237.4	432.3	669.7	14.21	0.07037
30	28.967	232.76	239.5	430.2	669.7	14.70	0.06802
32	30.967	236.35	243.6	426.1	669.7	15.69	0.06375
34	32.967	239.77	247.5	422.1	669.6	16.68	0.05995
36	34.967	243.04	251.2	418.3	669.5	17.68	0.05658
40	38.967	249.18	258.2	410.8	669	19.69	0.05078
45	43.967	256.23	266.5	401.7	668.2	22.25	0.04495
50	48.967	262.70	274.2	393.1	667.3	24.85	0.04024
60	58.967	274.29	288.4	376.6	665	30.21	0.03310
80	78.967	293.62	312.6	346.3	658.9	41.60	0.02404
100	98.967	309.53	334	317.1	651.1	54.21	0.01845
150	148.967	340.56	381.7	243.2	624.9	93.90	0.01065
200	198.967	364.08	431.4	150.7	582.1	161.2	0.00620
225.6	224.567	374.15	501.5	0°	501.5	315	0.00318

Table XI-B

Thermodynamic Properties of Steam (S.I. Units) Dry and Saturated Steam

Absolute pressure in 'bars'	Temperature in degrees "celsius"	Specific volume in cubic metre per kg.		Specific enthalpy in kilojoule per kg.		Specific entropy in kilojoule/kg °C	
		Saturated liquid	Saturated vapour	Saturated liquid	Saturated vapour	Saturated liquid	Saturated vapour
p	t	v'	v"	h'	h"	s'	s"
.01	6.98	0.001 000 2	129.208	29.30	2 514.2	0.1 059	8.9 756
.02	17.50	0.001 001 3	67.004	73.48	2 533.5	0.2 607	8.7 237
.03	24.08	0.001 002 7	45.665	101.05	2 545.5	0.3 545	8.5 776
.04	28.96	0.001 004 0	34.800	121.46	2 554.4	0.4 226	8.4 746
.05	32.88	0.001 005 3	28.192	137.82	2 561.5	0.4 764	8.3 951
.10	45.81	0.001 010 2	14.674	191.83	2 584.7	0.6 493	8.1 502
.20	60.06	0.001 017 2	7.649	251.40	2 609.7	0.8 320	7.9 085
.30	69.10	0.001 022 3	5.229	289.23	2 625.3	0.9 439	7.7 686
.40	75.87	0.001 026 5	3.993	317.58	2 636.8	1.0 259	7.6 700
.50	81.33	0.001 030 0	3.240	340.49	2 645.9	1.0 910	7.5 939
1.00	99.63	0.001 043 2	1.694 0	417.46	2 675.5	1.3 026	7.3 594
1.50	111.37	0.001 052 8	1.159 3	467.11	2 693.6	1.4 336	7.2 233
2.00	120.23	0.001 060 5	0.885 7	504.70	2 706.7	1.5 301	7.1 271
2.50	127.44	0.001 067 2	0.718 7	535.37	2 716.9	1.6 072	7.0 527
3.00	133.55	0.001 073 2	0.605 8	561.47	2 725.3	1.6 718	6.9 919
3.50	138.88	0.001 078 6	0.524 3	584.33	2 732.4	1.7 275	6.9 405
4.00	143.63	0.001 083 6	0.462 5	604.74	2 738.6	1.7 766	6.8 959
4.50	147.93	0.001 088 2	0.414 0	623.25	2 743.9	1.8 207	6.8 565
5.00	151.86	0.001 092 6	0.374 9	640.23	2 748.7	1.8 607	6.8 213
6.0	158.85	0.001 100 6	0.315 7	670.56	2 756.8	1.9 312	6.7 600
7.00	164.97	0.001 108 0	0.272 9	697.22	2 763.5	1.9 922	6.7 080
8.00	170.43	0.001 114 8	0.240 4	721.11	2 769.1	2.0 462	6.6 628
9.00	175.38	0.001 121 2	0.215 0	742.83	2 773.9	2.0 946	6.6 226
10.00	179.91	0.001 127 3	0.194 44	762.81	2 778.1	2.1 387	6.5 865
11.00	184.09	0.001 133 0	0.177.53	781.34	2 781.7	2.1 792	6.5 536
12.00	187.99	0.001 138 5	0.163 33	798.65	2 785.8	2.2 166	6.5 233

Table XI-B (Continued)

Absolute pressure in 'bars'	Temperature in degrees "celsius"	Specific volume in cubic metre per kg.		Specific enthalpy in kilojoule per kg		Specific entropy in kilojoule/kg °C	
		Saturated liquid	Saturated vapour	Saturated liquid	Saturated vapour	Saturated liquid	Saturated vapour
p	t	v'	v"	h'	h"	s'	s"
13.00	191.64	0.001 143 8	0.151 25	814.93	2 787.6	2.2 515	6.4 953
14.00	195.07	0.001 148 9	0.1 40 84	830.30	2 790.0	2.2 842	6.4 693
15.00	198.32	0.001 153 9	0.131 77	844.89	2 792.2	2.3 150	6.4 448
16.00	201.41	0.001 158 7	0.123 80	858.79	2 794.0	2.3 442	6.4 218
17.00	204.34	0.001 163 4	0.116 73	872.06	2 795.7	2.3 718	6.4 000
18.00	207.15	0.001 167 9	0.110 42	884.79	2 797.1	2.3 981	6.3 794
19.00	209.83	0.001 172 4	0.104 75	897.02	2 798.4	2.4 233	6.3 597
20.00	212.42	0.001 176 7	0.099 63	908.79	2 799.5	2.4 474	6.3 409
21.00	214.90	0.001 181 0	0.094 98	920.15	2 800.5	2.4 704	6.3 229
22.00	217.29	0.001 185 2	0.090 73	931.14	2 801.3	2.4 927	6.3 056
23.00	219.60	0.001 189 3	0.086 85	941.77	2 802.0	2.5 141	6.2 890
24.00	221.83	0.001 193 3	0.083 27	952.09	2 802.6	2.5 347	6.2 729
25.00	223.99	0.001 197 3	0.079.98	962.11	2 803.1	2.5 547	6.2 575
30.00	233.90	0.001 216 5	0.066 68	1 008.42	2 804.2	2.6 457	6.1 869
35.00	242.60	0.001 234 7	0.057 07	1 049.75	2 803.4	2.7 253	6.1 253
40.00	250.40	0.001 252 2	0.049 78	1 087.31	2 801.4	2.7 964	6.0 701
50.00	263.99	0.001 285 9	0.039 44	1 154.23	2 794.3	2.9 202	5.9 734
60.00	275.64	0.001 318 7	0.032 440	1 213.35	2 784.3	3.0 267	5.8 892
70.00	285.88	0.001 351 3	0.027 370	1 267.00	2 772.1	3.1 211	5.8 133
80.00	295.06	0.001 384 2	0.023 520	1 316.64	2 758.0	3.2 068	5.7 432
90.00	303.40	0.001 417	0.020 480	1 363.26	2 742.1	3.2 858	5.6 772
100.00	311.06	0.001 452 4	0.018 026	1 407.56	2 724.7	3.3 596	5.6 141
110.00	318.15	0.001 488 6	0.015 987	1 450.1	2 705.6	3.4 295	5.5 527
120.00	324.75	0.001 526 7	0.014 263	1 491.3	2 684.9	3.4 962	5.4 924
130.00	330.93	0.001 567 1	0.012 780	1 531.5	2 662.2	3.5 606	5.4 323
140.00	336.75	0.001 610 7	0.011 485	1 571.1	2 637.6	3.6 232	5.3 717
150.00	342.24	0.001 658 1	0.010 337	1 610.5	2 610.5	3.6 848	5.3 098
160.00	347.14	0.001 710 7	0.009 306	1 650.1	2 580.6	3.7 461	5.2 455
170.00	352.37	0.001 770 2	0.008 304	1 690.3	2 547.2	3.8 070	5.1 777
180.00	357.06	0.001 839 7	0.007 489	1 732.0	2 509.1	3.8 715	5.1 044
190.00	361.54	0.001 924 3	0.006 657	1 776.5	2 464.5	3.9 388	5.0 228
200.00	365.81	0.002 036	0.005 834	1 826.3	2 409.7	4.0 139	4.9 269

Table XII

Total Heat of Superheated Steam* (Izart[1] — after Mollier)

This table gives the total heat A using the same nomenclature. p' = corresponding approximate gauge pressure, in kg/cm²

A. METRIC UNITS

p	9	11	13	17	21	26	31	41	51	61
p'	8	10	12	16	20	25	30	40	50	60
$T°C$										
200	677.5	674.9	671.8							
210	683	680.8	678.2	672.5						
220	688.4	686.3	684	679.2	673.7					
230	693.5	691.6	689.6	685.3	680.6	673.8				
240	698.7	697	695.2	691.3	687.2	681.2	674.6			
250	703.8	702.2	700.6	697	693.2	688.1	682.4			
260	709	707.5	706	702.7	699.2	694.6	689.6	677.8		
270	714	712.6	711.2	708.1	705	700.8	696.3	686.1	673.6	
280	719	717.7	716.3	713.5	710.6	706.8	702.8	693.6	682.8	670.1
290	724.1	722.8	721.5	718.9	716.2	712.7	709	700.7	691.3	680.3
300	729.2	727.9	726.7	724.3	721.8	718.4	715	707.5	699.1	689.5
310	734.3	733.1	731.9	729.6	727.2	724.1	721	714.1	706.5	698
320	739.3	738.2	737.1	734.8	732.6	729.7	726.8	720.4	713.5	705.8
330	744.3	743.2	742.2	740	737.9	735.2	732.5	726.6	720.2	713.3
340	749.4	748.4	747.4	745.4	743.4	740.8	738.2	732.7	726.7	720.5
350	754.4	753.5	752.5	750.6	748.7	746.3	743.7	738.5	733	727.2
360	759.4	758.5	757.6	755.8	754	751.7	749.3	744.3	739.2	733.8
370	764.5	763.7	762.8	761.1	759.3	757.1	754.9	750.1	745.4	740.4
380	769.6	768.7	767.9	766.2	764.6	762.5	760.3	755.9	751.5	746.8
390	774.6	773.8	773	771.4	769.8	767.8	765.7	761.6	757.4	753
400	779.6	778.9	778.1	776.6	775.1	773.1	771.2	767.3	763.2	759.1
410	784.8	784.1	783.3	781.9	780.4	778.6	776.7	772.9	769.1	765.2
420	789.9	789.2	788.5	787.1	785.7	783.9	782.1	778.5	774.8	771.1
430	795	794.3	793.6	792.3	790.9	789.2	787.5	784.1	780.5	777
440	800.1	799.4	798.8	797.5	796.2	794.6	792.9	789.7	786.2	783
450	805.2	804.5	803.9	802.7	801.4	799.9	798.3	795.2	792	788.8
460	810.2	809.6	809	807.8	806.6	805.1	803.6	800.6	797.5	794.5
470	815.3	814.8	814.2	813	811.9	810.4	809	806.1	803.2	800.2
480	820.5	820	819.4	818.3	817.2	815.8	814.4	811.6	808.8	806
490	825.7	825.2	824.6	823.6	822.5	821.2	819.8	817.1	814.5	811.7
500	838.8	830.3	829.7	828.8	827.7	826.4	825.2	822.6	820	817.4
510	836	835.5	835	834.1	833	831.8	830.6	828.1	825.5	823
520	841.2	840.7	840.2	839.3	838.3	837.1	835.9	833.5	831	828.6
530	846.4	846	845.5	844.6	843.7	842.6	841.4	839	836.6	834.4
540	851.6	851.2	850.8	849.9	849	847.9	846.8	844.5	842.2	840
550	856.8	856.4	856	855.1	854.3	853.2	852.1	849.9	847.8	845.6

* From handbook of can-sugar engineering by E Hugot 3rd edition 1986

Table XIII

Value of (J—M)/(100—M) For Values of J From 40 to 90 & Values of M from 24 to 40

J	M 24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
90	.868	.866	.864	.863	.861	.859	.857	.855	.852	.851	.849	.846	.844	.841	.838	.836	.833
89	.855	.853	.851	.849	.847	.845	.842	.840	.838	.835	.833	.831	.828	.825	.822	.819	.816
88	.842	.840	.837	.835	.833	.830	.828	.826	.823	.821	.818	.816	.813	.808	.806	.803	.800
87	.828	.826	.824	.821	.819	.816	.814	.811	.808	.805	.803	.800	.797	.795	.790	.787	.783
86	.815	.813	.810	.808	.805	.802	.800	.797	.794	.791	.788	.785	.781	.777	.774	.770	.767
85	.802	.800	.797	.794	.791	.788	.785	.782	.779	.776	.772	.768	.765	.762	.757	.753	.750
84	.789	.786	.783	.780	.777	.774	.771	.768	.764	.761	.758	.754	.750	.746	.741	.737	.733
83	.776	.773	.770	.767	.763	.760	.757	.753	.750	.746	.742	.738	.734	.730	.725	.721	.717
82	.763	.760	.756	.753	.750	.746	.742	.739	.735	.731	.727	.723	.719	.714	.710	.705	.700
81	.750	.746	.743	.739	.736	.732	.728	.724	.720	.716	.712	.708	.703	.698	.693	.688	.683
80	.736	.733	.729	.726	.722	.718	.714	.710	.705	.701	.697	.692	.687	.682	.677	.672	.667
79	.723	.720	.716	.712	.708	.704	.700	.695	.691	.686	.682	.677	.672	.666	.661	.656	.650
78	.710	.706	.702	.698	.694	.690	.685	.681	.676	.671	.666	.661	.656	.651	.645	.639	.633
77	.697	.693	.689	.684	.680	.676	.671	.666	661	.656	.651	.646	.641	.634	.628	.622	.617
76	.684	.680	.675	.671	.666	.661	.657	.652	.647	.641	.636	.631	.625	.619	.613	.607	.600
75	.671	.666	.662	.657	.652	.647	.642	.637	.632	.627	.621	.615	.609	.603	.596	.590	.583
74	.657	.653	.648	.643	.638	.633	.628	.623	.617	.611	.606	.600	.594	.587	.581	.573	.567
73	.644	.640	.635	.630	.625	.619	.614	.608	.602	.597	.591	.585	.577	.571	.564	.557	.550
72	.631	.626	.621	.616	.611	.605	.600	.594	.588	.582	.586	.569	.562	.556	.548	.541	.533
71	.618	.613	.608	.602	.597	.591	.585	.579	.573	.567	.560	.554	.547	.539	.532	.524	.517
70	.605	.600	.594	.589	.583	.577	.571	.565	.559	.552	.545	.538	.531	.523	.516	.508	.500
69	.592	.586	.581	.575	.569	.563	.557	.550	.546	.538	.530	.522	.515	.508	.500	.491	.483
68	.578	.573	.567	.561	.555	.549	.542	.536	.529	.522	.515	.508	.500	.592	.484	.475	.466
67	.565	.560	.554	.547	.541	.535	.528	.521	.514	.507	.500	.492	.484	.476	.468	.459	.450
66	.552	.546	.540	.534	.527	.521	.514	.507	.500	.493	.485	.477	.469	.460	.452	.443	.433
65	.539	.533	.527	.520	.513	.507	.500	.492	.485	.478	.470	.461	.453	.445	.435	.426	.416

Table XIII (Continued)

J	M24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
64	.526	.520	.513	.506	.500	.492	.485	.478	.470	.463	.455	.446	.437	.428	.419	.410	.400
63	.513	.506	.500	.493	.486	.478	.471	.463	.456	.448	.440	.431	.422	.413	.403	.393	.384
62	.500	.493	.486	.479	.472	.464	.457	.449	.441	.433	.424	.416	.406	.396	.387	.377	.367
61	.486	.480	.472	.465	.458	.450	.442	.434	.426	.417	.409	.400	.391	.381	.371	.362	.350
60	.473	.466	.459	.452	.444	.436	.428	.420	.412	.403	.395	.385	.375	.365	.355	.344	.334
59	.460	.453	.445	.438	.430	.422	.414	.405	.397	.388	.379	.369	.359	.349	.338	.328	.317
58	.447	.440	.432	.424	.416	.408	.400	.391	.382	.373	.364	.354	.344	.333	.322	.311	.300
57	.434	.426	.418	.410	.402	.394	.385	.376	.368	.358	.348	.339	.328	.317	.306	.294	.283
56	.421	.413	.405	.397	.388	.380	.371	.362	.353	.343	.334	.323	.312	.301	.290	.279	.269
55	.407	.400	.391	.383	.375	.366	.357	.347	.338	.328	.318	.308	.297	.286	.274	.262	.250
54	.394	.386	.378	.369	.361	.352	.342	.333	.324	.313	.303	.292	.281	.270	.258	.245	.233
53	.381	.373	.364	.356	.347	.338	.328	.318	.309	.299	.288	.277	.266	.254	.242	.229	.217
52	.368	.360	.351	.342	.333	.323	.314	.304	.294	.284	.273	.262	.250	.238	.226	.216	.200
51	.355	.346	.337	.328	.319	.309	.300	.289	.279	.269	.258	.246	.234	.222	.210	.198	.183
50	.342	.333	.324	.315	.305	.295	.285	.275	.265	.253	.242	.231	.219	.206	.193	.180	.167
49	.328	.320	.310	.301	.291	.281	.271	.260	.250	.239	.227	.215	.203	.190	.177	.164	.150
48	.315	.306	.297	.287	.277	.267	.257	.246	.236	.224	.212	.200	.187	.175	.161	.147	.133
47	.302	.293	.283	.273	.263	.253	.242	.231	.220	.209	.197	.185	.172	.159	.145	.131	.117
46	.289	.280	.270	.260	.250	.239	.228	.217	.206	.194	.183	.169	.156	.143	.129	.115	.100
45	.276	.266	.256	.246	.236	.225	.214	.202	.191	.178	.167	.154	.141	.127	.113	.098	.083
44	.263	.253	.243	.232	.222	.211	.200	.188	.177	.165	.153	.139	.124	.111	.097	.083	.068
43	.250	.240	.229	.219	.208	.197	.185	.173	.162	.149	.136	.123	.109	.095	.081	.065	.050
42	.236	.226	.216	.205	.194	.183	.171	.159	.147	.135	.121	.107	.094	.079	.064	.049	.033
41	.223	.213	.202	.191	.180	.169	.157	.144	.133	.119	.106	.092	.078	.063	.048	.033	.017
40	.210	.200	.189	.178	.166	.154	.142	.130	.118	.105	.091	.077	.063	.047	.032	.016	–

Table XIV

Value of (100—J)/(J—M) x 1.2 For values of J from 40—90 & values of M from 24—40

J	M 24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
90	.181	.184	.187	.190	.193	.196	.199	.203	.207	.210	.214	.218	.222	.226	.231	.235	.240
89	.203	.206	.209	.212	.216	.219	.223	.227	.232	.236	.240	.244	.249	.254	.259	.264	.269
88	.225	.228	.232	.236	.240	.244	.248	.252	.257	.262	.267	.272	.277	.282	.288	.294	.300
87	.247	.251	.255	.260	.264	.268	.273	.278	.284	.289	.294	.300	.306	.312	.318	.325	.332
86	.270	.275	.279	.284	.289	.294	.300	.305	.311	.319	.323	.329	.336	.343	.350	.357	.367
85	.295	.300	.305	.310	.315	.321	.327	.333	.339	.346	.353	.360	.367	.375	.383	.391	.400
84	.320	.325	.331	.336	.342	.349	.355	.362	.369	.376	.384	.392	.400	.408	.417	.427	.436
83	.345	.351	.357	.364	.370	.377	.384	.392	.400	.408	.416	.425	.433	.443	.453	.404	.474
82	.372	.378	.385	.392	.399	.407	.415	.423	.431	.440	.450	.459	.470	.480	.490	.502	.514
81	.399	.407	.414	.422	.430	.438	.447	.455	.465	.475	.485	.496	.506	.518	.530	.543	.556
80	.428	.436	.444	.452	.461	.470	.480	.489	.500	.510	.522	.533	.545	.558	.571	.585	.600
79	.458	.466	.475	.484	.494	.504	.514	.525	.536	.547	.500	.573	.586	.600	.615	.630	.645
78	.488	.498	.507	.517	.528	.538	.549	.561	.573	.586	.600	.614	.628	.644	.660	.677	.695
77	.520	.530	.541	.552	.563	.575	.587	.600	.613	.627	.641	.657	.673	.690	.707	.726	.746
76	.553	.564	.576	.587	.600	.612	.626	.640	.654	.669	.685	.702	.720	.738	.757	.778	.800
75	.588	.600	.612	.625	.638	.652	.666	.681	.697	.711	.731	.750	.769	.789	.810	.833	.856
74	.624	.636	.649	.663	.678	.693	.709	.725	.743	.761	.780	.800	.820	.843	.867	.891	.918
73	.661	.674	.689	.704	.720	.736	.753	.771	.790	.810	.830	.853	.875	.900	.925	.953	.982
72	.700	.714	.730	.746	.763	.781	.799	.819	.840	.861	.884	.908	.933	.960	.989	1.018	1.050
71	.740	.756	.773	.790	.809	.828	.848	.870	.892	.915	.940	.967	.994	1.023	1.054	1.087	1.122
70	.782	.799	.818	.837	.857	.878	.900	.923	.947	.973	1.000	1.028	1.049	1.091	1.124	1.161	1.200
69	.826	.845	.865	.885	.907	.929	.953	.978	1.005	1.033	1.062	1.094	1.128	1.162	1.200	1.240	1.282
68	.872	.893	.914	.936	.960	.984	.010	.037	1.067	1.097	1.129	1.163	1.200	1.239	1.280	1.324	1.371
67	.920	.942	.965	.989	.015	.042	.078	.099	1.132	1.164	1.200	1.237	1.278	1.320	1.365	1.414	1.464
66	.971	.995	.020	.046	.073	.102	.133	.165	1.200	1.236	1.277	1.316	1.360	1.406	1.457	1.511	1.570
65	.024	.050	.076	.105	.135	.166	.200	.235	1.272	1.312	1.354	1.400	1.448	1.500	1.556	1.615	1.680

Table XIV(Continued)

J	M 24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
64	.080	.107	.136	.167	.200	.234	.270	.309	1.350	1.392	1.441	1.489	1.543	1.600	1.661	1.728	1.802
63	.138	.168	.200	.233	.268	.305	.345	.387	1.431	1.480	1.531	1.593	1.642	1.708	1.777	1.850	1.933
62	.200	.232	.266	.302	.341	.381	.425	.470	1.520	1.572	1.628	1.688	1.752	1.824	1.900	1.987	2.070
61	.264	.299	.337	.376	.418	.462	.509	.560	1.614	1.671	1.731	1.800	1.871	1.950	2.030	2.127	2.230
60	.333	.371	.411	.454	.500	.548	.599	.655	1.715	1.777	1.847	1.920	2.000	2.087	2.180	2.286	2.400
59	.405	.447	.490	.537	.587	.640	.696	.757	1.820	1.891	1.968	2.050	2.139	2.236	2.343	2.460	2.589
58	.482	.527	.575	.625	.680	.737	.800	.866	1.940	2.010	2.100	2.191	2.290	2.400	2.520	2.652	2.800
57	.563	.612	.664	.720	.779	.842	.911	.984	2.070	2.150	2.243	2.345	2.460	2.580	2.720	2.866	3.040
56	.650	.703	.759	.820	.885	.955	.030	.112	2.200	2.290	2.400	2.514	2.640	2.779	2.930	3.106	3.300
55	.741	.800	.862	.928	.000	.076	.160	.250	2.370	2.454	2.570	2.700	2.840	3.000	3.170	3.375	3.600
54	.840	.903	.971	.044	.123	.208	.300	.400	2.500	2.620	2.760	2.905	3.070	3.247	3.450	3.680	3.940
53	.944	.014	.088	.169	.256	.349	.452	.563	2.680	2.820	2.970	3.133	3.320	3.525	3.760	4.028	4.430
52	.057	.133	.215	.304	.400	.504	.618	.742	4.880	3.030	3.200	3.388	3.600	3.840	4.110	4.430	4.810
51	.177	.261	.352	.449	.556	.672	.800	.940	3.000	3.260	3.460	3.675	3.930	4.200	4.530	4.900	5.350
50	.307	.400	.500	.608	.727	.857	.000	.157	3.330	3.530	3.750	4.000	4.280	4.615	5.000	5.454	6.000
49	.448	.550	.660	.781	.914	.059	.221	.400	3.600	3.820	4.080	4.371	4.700	5.100	5.570	6.120	6.800
48	.599	.713	.836	.971	.120	.284	.466	.670	3.900	4.160	4.450	4.800	5.200	5.673	6.240	6.933	7.790
47	.765	.890	.028	.179	.347	.533	.741	.974	4.240	4.540	4.900	5.300	5.800	6.360	7.070	7.950	8.190
46	.945	.085	.240	.410	.600	.811	.050	.320	4.630	4.980	5.400	5.891	6.470	7.200	8.100	9.257	10.400
45	.142	.300	.473	.666	.882	.125	.399	.714	5.080	5.500	6.000	6.600	7.340	8.250	9.430	11.000	13.200
44	.360	.536	.733	.952	.200	.479	.800	.169	5.600	6.110	6.720	7.466	8.400	9.600	11.200	13.440	16.800
43	.600	.800	.023	.274	.560	.885	.261	.700	6.210	6.840	7.600	8.550	9.760	11.400	13.700	17.100	22.400
42	.866	.094	.350	.640	.971	.353	.800	.327	6.950	7.730	8.670	9.943	11.580	13.920	17.300	23.200	34.700
41	.164	.425	.720	.057	.446	.900	.436	.080	7.870	8.850	10.110	11.800	14.130	17.700	23.600	35.400	
40	.500	.800	.142	.538	.000	.545	.200	.000	9.000	10.280	12.000	14.400	18.000	24.000	36.000		

(Courtesy : Triveni Engg. Works Ltd., Khatauli)

Table XV

Crystal Content of Massecuites*

Mass purity	Purity drop										
	15	16	17	18	19	20	21	22	23	24	25
90	60.0	61.5	63.0	64.3	65.5	66.7	–	–	–	–	–
89	57.7	59.3	60.7	62.1	63.3	64.5	65.6	–	–	–	–
88	55.6	57.1	58.6	60.0	61.3	62.5	63.6	64.7	–	–	–
87	53.6	55.2	56.7	58.1	59.4	60.6	61.8	62.9	63.9	–	–
86	51.7	53.3	54.8	56.3	57.6	58.8	60.0	61.1	62.1	63.2	–
85	50.0	51.6	53.0	54.5	55.9	57.1	58.3	59.4	60.5	61.5	62.5
84	48.4	50.0	51.5	52.9	54.3	55.6	56.8	57.9	59.0	60.0	61.0
83	46.9	48.5	50.0	51.4	52.8	54.1	55.3	56.4	57.5	58.5	59.5
82	45.5	47.1	48.6	50.0	51.4	52.6	53.8	55.0	56.1	57.1	58.1
81	44.1	45.8	47.2	48.6	50.0	51.3	52.5	53.7	54.8	55.8	56.8
80	42.9	44.4	45.9	47.4	48.7	50.0	51.2	52.4	53.5	54.5	55.6
79	41.7	43.2	44.7	46.2	47.5	48.8	50.0	51.2	52.3	53.3	54.3
78	40.5	42.1	43.6	45.0	46.3	47.6	48.8	50.0	51.1	52.2	53.2
77	39.5	41.0	42.5	43.9	45.2	46.5	47.7	48.9	50.0	51.1	52.1
76	38.5	40.0	41.5	42.9	44.2	45.5	46.7	47.8	48.9	50.0	51.0
75	37.5	39.0	40.5	41.9	43.2	44.4	45.7	46.8	47.9	49.0	50.0
74	36.6	38.1	39.5	40.9	42.2	43.5	44.7	45.8	46.9	48.0	49.0
73	35.7	37.2	38.6	40.0	41.3	42.6	43.7	44.9	46.0	47.1	48.1
72	34.9	36.4	37.8	39.1	40.4	41.7	42.9	44.0	45.1	46.2	47.2
71	34.1	35.6	37.0	38.3	39.6	40.8	42.0	43.1	44.2	45.3	46.3
70	33.3	34.8	36.2	37.5	38.8	40.0	41.2	42.3	43.4	44.4	45.5
	15	16	17	18	19	20	22	24	26	28	30
69	32.6	34.0	35.4	36.7	38.0	39.2	41.5	43.6	45.6	47.5	49.2
68	31.9	33.3	34.7	36.0	37.3	38.5	40.7	42.9	44.8	46.7	48.4
67	31.2	32.7	34.0	35.3	36.5	37.7	40.0	42.1	44.1	45.9	47.6
66	30.6	32.0	33.3	34.6	35.8	37.0	39.3	41.4	43.3	45.2	46.9
65	30.0	31.4	32.7	34.0	35.2	36.4	38.6	40.7	42.6	44.4	46.2
64	29.4	30.8	32.1	33.3	34.5	35.7	37.9	40.0	41.9	43.8	45.5
63	28.8	30.2	31.5	32.7	33.9	35.1	37.3	39.3	41.3	43.1	44.8
62	28.3	29.6	30.9	32.1	33.3	34.5	36.7	38.7	40.6	42.4	44.1
61	27.8	29.1	30.4	31.6	32.8	33.9	36.1	38.1	40.0	41.8	43.5
60	27.3	28.6	29.8	31.0	32.2	33.3	35.5	37.5	39.4	41.2	42.9
59	26.8	28.1	29.3	30.5	31.7	32.8	34.9	36.9	38.8	40.6	42.3
58	26.3	27.6	28.8	30.0	31.1	32.3	34.4	36.4	38.2	40.0	41.7
57	25.9	27.1	28.3	29.5	30.6	31.7	33.8	35.8	37.7	39.4	41.1
56	25.4	26.7	27.9	29.0	30.2	31.3	33.3	35.3	37.1	38.9	40.5
55	25.0	26.2	27.4	28.6	29.7	30.8	32.8	34.8	36.6	38.3	40.0

* With apparent purities the crystal content per cent Brix is derived. The use true purities gives crystal per cent dry substance. To obtain crystal per cent massecuite multiply by Brix or dry substance per unit of massecuite.

Table XVI

MENSURATION OF SURFACES AND SOLIDS

Circumference of a circle	=	π x diameter
Area of a circle	=	$\pi/4$ x (diameter)^2
Area of sector of a circle	=	(Radius/2) x length of arc
Area of square, parallelogram, rectangle, rhombus or rhomboid	=	base x height
Area of trapezium	=	½ x sum of parallel sides x height
Area of regular polygon	=	½ radius of inscribed circle x length of one side x no. of sides
Area of triangle	=	½ base x altitude
Area of parabola	=	½ x base x altitude
Area of ellipse	=	$\pi/4$ x major axis x minor axis
Area of cycloid	=	3 x area of generating circle
Surface area of sphere	=	π x (diameter)^2
Volume of sphere	=	$\pi/6$ x (diameter)^2
Volume of parabolid	=	½ x volume of circumscribing cylinder
Volume of prism	=	area of base x altitude
Volume of cylinder	=	$\pi/4$ x (diameter)^2 x height
Volume of pyramid	=	1/3 x area of base x height
Volume of cone	=	1/3 x $\pi/4$ x (diameter of base)^2 x height
Length of arc	=	Radius of circle x angle subtended at the centre in radians (=r θ)
One radian	=	$^1/_3 180/\pi = 57.4°$

Table XVII-A

S. I. Units, Their nomenclature and symbols

Recent version of metric, units known as System International d' units (SI) is now more widely accepted. The various SI units are,

Physical Quantity	Name	Symbol
1. **Basic Units**		
Length	Meter	m
Mass	Kilogram	Kg
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd
2. **Derived Units**		
Force	Newton	N
Work, energy or quantity of heat	Joule	J
Power	Watt	W
Electric Charge	Coulomb	C
Pressure	Pascal	Pa
Electrical Potential difference	Volt	V

Table XVII-B

Prefix Symbols and their multiplication factors

Prefix used	Prefix symbol	Multiplication factor
Tara	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	K	10^{3}
Hecto	h	10^{2}
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}
Atto	a	10^{-18}

Table XVII-C

Factors for Converting One System of Units into Another*

	FPS to metric and S.I.			Metric and S.I. to FPS		
Measurement	Unit	To convert into	Multiply by factor	Unit	To convert into	Multiply by factor
Length	inch	millimetres	25.4	millimetres	inch	0.3927
	foot	metres	0.3048	metres	feet	3.28
	yard	metres	0.9144	metres	yard	1.0936
	mile	kilometres	1.6093	kilometre	mile	0.621
Area	sq in	sq cm	6.451	sq cm	sq in	0.155
	sq ft	sq m	0.0929	sq m	sq ft	10.764
	acre	hectare	0.4047	hectare	acre	2.471
Volume	cu in	cc	16.3871	cc	cu in	0.061
	imperial gallon	litres	4.546	litre	imperial gallons	0.22
	gallon	cum	0.004546	cum		220
	U.S. gallon	litres	3.785	litre	U.S. gallon	0.2642
	cft	litre	28.316	litre	cft	0.0353
	cft	cum	0.0283	cum	cft	35.38
Weight	lb.	kg	0.4536	kg	lb	2.205
	cwt	kg	50.802	kg	cwt	0.0197
	short (U.S.) ton (2000 lb)	tonne	0.907	tonne	short (U.S.) (2000 lb) ton	1.102
	long ton (2240 lb)	tonne	1.016	tonne	long ton	0.98421
Density	lb/cft	kg/m^3	16.02	kg/m^3	lb/cft	0.0625
	lb/cft	kg/litre	0.016	kg/litre	lb/cft	62.424
	lb/in^3	kg/cm^3	27.6799	kg/cm^3	lb/in^3	0.0362

(*From : Power Plant Engineering—by Mahesh Varma)

Table XVII-C (Continued)

	FPS to metric and S.I.			Metric and S.I. to FPS		
Measurement	Unit	To convert into	Multiply by factor	Unit	To convert into	Multiply by factor
Moment of Inertia	lb/ft^2	kg/m^2	0.1686	kg/m^2	lb/ft^2	5.933
Velocity	ft/sec	m/sec	0.3048	m/sec	ft/sec	3.28
	ft/min	m/sec	5.09×10^{-3}	m/sec	ft/min	196.85
Temperature	°F	°C	$\frac{5}{9}(F-32)$	°C	$\frac{9}{5}$ °F	$\frac{1}{2}\times C+32$
Discharge	cusec	lit/sec	28.316	lit/sec	cusec	0.0353
	cft/min	lit/sec	0.472	lit/sec	cft/min	2.22
	gal/min	lit/sec	0.0757	lit/sec	gal/min	13.22
	gal/min	m^3/sec	0.757×10^{-4}	m^3/sec	gal/min	13.220

Table XVII-C (Continued)

Measurement	Metric to SI			SI to Metric		
	Unit	To convert into	Multiply by factor	Unit	To convert into	Multiply by factor
Pressure and Head	kgs/cm^2	N/cm^2	9.807	N/cm^2	kgs/cm^2	0.102
	kgs/cm^2	N/m^2	98067	N/m^2	kgs/cm^2	0.102×10^{-5}
	atm	N/m^2	101325	N/m^2	atm	0.987×10^{-5}
	mm H_2O	N/m^2	9.807	N/m^2	mm H_2O	0.102
	mm Hg	N/m^2	133.322	N/m^2	mm Hg	7.5×10^{-3}
Viscosity	dyne second per cm^2 or poise	N.s/m^2	0.1	N.s/m^2	dyne second per cm^2 or poise	10
kinematic viscosity	cm^2 per second or stroke	m^2/s	10^{-4}	m^2/s	cm^2 per second or stroke	10^4
Energy	kgsm	J	9.807	J	kg.-m	0.102
Power	H.P. (75 kg.-m/s)	W	735.499	W	H.P. (75 kg.-m/s)	1.3596×10^{-3}
Heat	kcal	J	4186.8	J	kcal	2.388×10^{-4}
	kcal/kg	J/kg.	4186.8	J/kg.	kcal/kg.	2.388×10^{-4}
	kcal/sq m	J/m^2	4186.8	J/m^2	kcal/sq m	2.388×10^{-4}
	kcal	Nm	4186.8	Nm	kcal	2.388×10^{-4}
Thermal Conductivity	kcal/hr-°C-m	J/s-°C-m or W/°C-m	1.163	J/s-°C-m or W/°C-m	kcal/hr-°C-m	0.86
	kcal/hr-°C-m^2	J/s-°C-m^2 or W/°C-m^2	1.163	J/s-°C-m^2 W/°C-m^2	kcal/hr-°C-m^2	0.86
Force	kgs	N	9.807	N*	kgs	0.102

*N (Neutron = Force of body of mass 1.0 kg with acceleration of 1 M/Sec/Sec).

Table XVII-C (Continued)

Measurement	SI to FPS			FPS to SI		
	Unit	To convert into	Multiply by factor	Unit	To convert into	Multiply by factor
Pressure and Head	N/cm^2	lbs/sq. in	1.45	lbs/sq. in	N/cm^2	0.6895
	N/m^2	lbs/sq. in	1.45×10^{-4}	lbs/sq. in	N/m^2	68.95
	N/m^2	ton/sq in	0.06475	ton/sq in	N/m^2	15.444
	N/m^2	in Hg	2.953×10^{-4}	in Hg	N/m^2	3386.39
	N/m^2	ft H_2O	3.345×10^{-4}	ft H_2O	N/m^2	2989.07
Viscosity	$N.s/m^2$	$lb/sec/ft^2$	2.0885×10^{-2}	$lb/sec/ft^2$	$N.s/m^2$	47.88
Kinematic Viscosity	m^2/S	ft^2/sec	10.764	ft^2/sec	m^2/sec	0.0929
Energy	J	ft. lb.	0.737562	ft-lb.	J	1.35582
Power	W	H.P. (550 ft lb/sec)	1.341×10^{-3}	H.P. (550 ft lb/sec)	W	745.7
Heat	J	Btu	9.478×10^{-4}	Btu	J	1055.06
	J/kg	Btu/lb	4.299×10^{-4}	Btu/lb	J/kg	2326
	J/m^2	Btu/sq ft	11356.5	Btu/sq ft	J/m^2	0.88×10^{-4}
	Nm	Btu	9.478×10^{-4}	Btu	N.m	1055.06
Thermal Conductivity	J/s-°C-m or W °C-m	Btu/hr-°F-ft	0.578	Btu/hr-°F-ft	J/s-°C-m or W/°C-m	1.73
	$J/s\text{-}°C\text{-}m^2$ or W/°C-m	Btu/hr-°F-ft^2	0.176	Btu/hr-°F-ft^2	$J/s\text{-}°C\text{-}m^2$ or W/°C-m	5.67
Force	N	lb	0.2248	lb	N	4.448

Table XVII-C (Continued)

Measurement	FPS to Metric			Metric to FPS		
	Unit	To convert into	Multiply by factor	Unit	To convert into	Multiply by factor
Pressure and Head	lbs/sq. in	kgs/cm^2	0.0703	kgs/cm^2	lb*f*/sq in	14.22
	lb*f*/sq in	atm	0.068	atm	lb*f*/sq in	14.7
	long ton/sq in	kgs/cm^2	157.5	kgs/cm^2	long ton*f*/sq in	0.00635
	in Hg	mm H_2O	345	mm H_2O	in Hg	0.0029
	ft H_2C	mm Hg	22.42	mm Hg	ft H_2O	0.0446
Viscosity	lb sec/ft^2	dyne second/ cm^2 or poise	478.8	dyne second/ cm^2 or poise	lb*f*sec/ft^2	2.0885×10^{-3}
Kinematic Viscosity	ft^2/sec	cm^2/sec or stoke	929.4	cm^2/sec or stoke	ft^2/sec	1.076×10^{-3}
Energy	ft. lbs	Kgm	0.1382	Kgm	ft lb*f*	7233
Power	H.P.(550 ft lbs/sec) sec)	H.P.(75 kgm / sec)	1.0139	H.P.(75 kgm / sec)	H.P.(550 ft lbs/ sec)	09863
Heat	Btu	kcal	0.252	kcal	Btu	3.968
	Btu/lb	kcal/kg	0.5556	kcal/kg	Btu/lb	1.8
	Btu/sq ft	kcal/m^2	2.7126	kcal/m^2	Btu/sq ft	0.3687
	Btu	kg*f* m	107.586	kg*f* m	Btu	9.2949×10^{-3}
Thermal Conductivity	Btu hr-°F-ft	kcal/hr-°C-m	1.49	kcal/hr-°C-m	Btu/hr-°F-ft	0.672
	Btu/hr-°F-ft^2	kcal/hr-°C-m^2	4.88	kcal/hr-°C-m^2	Btu/hr-F-ft^2	0.205
Force	lb*f*	kg*f*	0.453	kg*f*	lb	2.205

Table XVIII*

Table of Constants

1 cft of water	=	62.4 lb of fresh water
	=	64 lb of sea water
	=	6.23 Imperial gallons
	=	7.48 U.S. gallons
	=	0.0283 cum
	=	28.375 litres
1 cum of water	=	1000 kg.
	=	1000 litre
	=	35.3 cft
	=	220 Imperial gallons
	=	264 U.S. gallons
1 cusec	=	375 Imperial gallons/min
	=	450 U.S. gallons/min
	=	0.0283 cum/sec
1 litre of water	=	0.0353 cft
	=	61 cu in
	=	2.2 lb
	=	0.22 Imperial gallon
	=	0.264 U.S. gallon
1 Imperial gallon	=	10 lb
	=	0.16 cft
	=	277 cu in
	=	1.2 U.S. gallon
	=	4.56 litre
1 U.S. gallon	=	8.33 lb
	=	0.133 cft
	=	231 cu in
	=	0.83 Imperial gallon
	=	3.8 litre
1 Ton (long)	=	2240 lb
	=	36 cft of fresh water
	=	35 cft of salt water
	=	224 Imperial gallons of fresh water

(*From : Power Plant Engineering—by Mahesh Varma)

Table XVIII (Continued)

1 Horse power (FPS)	=	550 ft-lb*f*/sec
	=	33000 ft lb*f*/mın
	=	1.0139 metric horse power
	=	0.7457 kW
1 Horse power (metric)	=	75 kg m/sec
	=	4500 kg m/sec
	=	0.9863 horse power (FPS)
	=	0.735 499 kW
Acceleration due to gravity	=	32.18 ft/sec ($\approx$ 32.2 ft/sec)
	=	9.80665 m/sec ($\approx$ 9.807 m/sec)
Stefan Boltzman constant	=	4.86×10^{-8} k cal/hr-m^2-$^\circ$K^4
	=	5.67×10^{-8} W/m^2 $^\circ$K^4
	=	5.67×10^{-8} J/sec-m^2-$^\circ$K^4
	=	0.17×10^{-8} Btu/hr-ft^2-$^\circ$R^4.

Table XVIII (Continued)

	=	218 Imperial gallons of salt water
	=	268.8 U.S. gallons of fresh water
	=	261.6 U.S. gallons of salt water
	=	1 cum (approx)
1 Normal or standard atmosphere	=	14.6959 lbf/sq in (≈ 14.7 psi)
	=	29.9213 in Hg (≈ 30 in Hg)
	=	33.8985 ft H_2O (≈ 34 ft H_2O)
	=	1.03323 kgf/cm^2 (≈ 1.03 kgf/cm^2)
	=	10.3323 m H_2O (≈ 10.3 m H_2O)
	=	760 mm Hg or 760 torr
	=	1.01325 bar (≈ 1.01 bar)
	=	101325 N/m^2
1 technical atmosphere	=	1 kgf/cm^2
	=	735.559 mm Hg (≈ 736 mm Hg)
	=	735.559 torr (≈ 736 torr)
	=	10 m H_2O
	=	14.2233 lbf/sq in (≈ 14.22 psi)
	=	28.959 in Hg (≈ 29 in Hg)
	=	32.8084 ft H_2O (≈ 32.81 ft H_2O)
	=	0.980665 bar (≈ 0.981 bar)
	=	98066.5 N/m^2
1 bar	=	10^5 N/m^2
	=	750.062 mm Hg (≈ 750 mm Hg)
	=	750.062 torr (≈ 750 torr)
	=	10.1972 m H_2O (≈ 10.2 m H_2O)
	=	14.5038 lbf/sq in (≈ 14.5 psi)
	=	29.53 in Hg
	=	33.4553 ft H_2O (≈ 33.5 ft H_2O)
	=	1.01972 kgf/cm^2 (≈ 1.02 kgf/cm^2)
	=	0.986923 at m (≈ 0.987 atm)

Table XIX

Atomic Weights[a]

(Scaled to the relative atomic mass, A_r (^{12}C) = 12)

The atomic weight of many elements are not invariant but depend on the origin and treatment of the material. The footnotes to this Table elaborate the types of variation to be expected for individual elements. The values of $A_r(E)$ given here apply to elements as they exist naturally on earth and to certain artificial elements. When used with due regard to the footnotes they are considered reliable to ±1 in the last digit or ±3 when followed by an asterisk*. Values in parentheses are used for certain radioactive elements whose atomic weights cannot be quoted precisely without knowledge of origin; the value given is the atomic mass number of the isotope of that element of longest known half life.

Name	Symbol	Atomic Number	Atomic Weight	Footnotes
Actinium	Ac	89	227.0278	z
Aluminium	Al	13	26.98154	
Americium	Am	95	(243)	
Antimony	Sb	51	121.75*	
Argon	Ar	18	39.948*	w, x
Arsenic	As	33	74.9216	
Astatine	At	85	(210)	
Barium	Ba	56	137.33	x
Berkelium	Bk	97	(247)	
Beryllium	Be	4	9.01218	
Bismuth	Bi	83	208.9804	
Boron	B	5	10.81	w, y
Bromine	Br	35	79.904	
Cadmium	Cd	48	112.41	x
Caesium	Cs	55	132.9054	
Calcium	Ca	20	40.08	x
Californium	Cf	98	(251)	
Carbon	C	6	12.011	w
Cerium	Ce	58	140.12	x
Chlorine	Cl	17	35.453	
Chromium	Cr	24	51.996	
Cobalt	Co	27	58.9332	
Copper	Cu	29	63.546*	w
Curium	Cm	96	(247)	
Dysprosium	Dy	66	162.50*	
Einsteinium	Es	99	(254)	
Erbium	Er	68	167.26*	
Europium	Eu	63	151.96	x
Fermium	Fm	100	(257)	
Fluorine	F	9	18.998403	
Francium	Fr	87	(223)	
Gadolinium	Gd	64	157.25*	x
Gallium	Ga	31	69.72	

* International Atomic Weights.

Name	Symbol	Atomic Number	Atomic Weight	Footnotes
Germanium	Ge	32	72.59*	
Gold	Au	79	196.9665	
Hafnium	Hf	72	178.49*	
Helium	He	2	4.00260	x
Holmium	Ho	67	164.9304	
Hydrogen	H	1	1.0079	w
Indium	In	49	114.82	x
Iodine	I	53	126.9045	
Iridium	Ir	77	192.22*	
Iron	Fe	26	55.847*	
Krypton	Kr	36	83.80	x, y
Lanthanum	La	57	138.9055*	x
Lawrencium	Lr	103	(260)	
Lead	Pb	82	207.2	x, w
Lithium	Li	3	6.941*	w, x, y
Lutetium	Lu	71	174.97	
Magnesium	Mg	12	24.305	x
Manganese	Mn	25	54.9380	
Mendelevium	Md	101	(258)	
Mercury	Hg	80	200.59*	
Molybdenum	Mo	42	95.94	
Neodymium	Nd	60	144.24*	x
Neon	Ne	10	20.179*	y
Neptunium	Np	93	237.0482	z
Nickel	Ni	28	58.70	
Niobium	Nb	41	92.9064	
Nitrogen	N	7	14.0067	
Nobelium	No	102	(259)	
Osmium	Os	76	190.2	x
Oxygen	O	8	15.9994*	w
Palladium	Pd	46	106.4	x
Phosphorus	P	15	30.97376	
Platinum	Pt	78	195.09*	
Plutonium	Pu	94	(244)	
Polonium	Po	84	(209)	
Potassium	K	19	39.0983*	
Praseodymium	Pr	59	140.9077	
Promethium	Pm	61	(145)	
Protactinium	Pa	91	231.0359	z
Radium	Ra	88	226.0254	x, z
Radon	Rn	86	(222)	
Rhenium	Re	75	186.207	
Rhodium	Rh	45	102.9055	
Rubidium	Rb	37	85.4678*	x
Ruthenium	Ru	44	101.07*	x
Samarium	Sm	62	150.4	x
Scandium	Sc	21	44.9559	
Selenium	Se	34	78.96*	
Silicon	Si	14	28.0855*	
Silver	Ag	47	107.868	x
Sodium	Na	11	22.98977	
Strontium	Sr	38	87.62	x
Sulfur	S	16	32.06	w

Name	Symbol	Atomic Number	Atomic Weight	Footnotes
Tantalum	Ta	73	180.9479*	
Technetium	Tc	43	(97)	
Tellurium	Te	52	127.60*	x
Terbium	Tb	65	158.9254	
Thallium	Tl	81	204.37*	
Thorium	Th	90	232.0381	x, z
Thulium	Tm	69	168.9342	
Tin	Sn	50	118.69*	
Titanium	Ti	22	47.90*	
Tungsten (Wolfram)	W	74	183.85*	
Uranium	U	92	238.029	x, y
Vanadium	V	23	50.9414*	
Xenon	Xe	54	131.30	x, y
Ytterbium	Yb	70	173.04*	
Yttrium	Y	39	88.9059	
Zinc	Zn	30	65.38	
Zirconium	Zr	40	91.22	x

a By permission of the International Union of Pure and Applied Chemistry and Pergamon Press Limited, Oxford, England. See also *Pure and Applied Chemistry*, Vol. 47, pp. 75-95.

w Element for which known variations in isotopic composition in normal terrestrial material prevent a more precise atomic weight being given; A_r (E) values should be applicable to any "normal" material.

x Element for which geological specimens are known in which the element has an anomalous isotopic composition, such that the difference in atomic weight of the element in such specimens from that given in the Table may exceed considerably the implied uncertainty.

y Element for which substantial variations in A_r from the value given can occur in commercially available material because of inadvertent or undisclosed change of isotopic composition.

z Element for which the value of A_r is that of the radioisotope of longest half-life.

(Table XIX taken from cane sugar handbook JCP Chen 11th Edition)

TABLE XX

Volume of Sucrose Solutions at Different Temperatures [a]
(Volume at 20°C = 1.0000)
Percentage of Sucrose by Weight

Temperature (C)	0	5	10	15	20	25	30	35	40	50	60	70	75
0	0.9984	0.9976	0.9969	0.9964	0.9958	0.9954	0.9949	0.9945	0.9941	0.9934	0.9929	0.9926	0.9927
5	.9982	.9978	.9974	09970	.9966	.9963	.9960	.9957	.9954	.9949	.9946	.9944	.9945
10	.9985	.9983	.9981	.9978	.9976	.9974	.9972	.9970	.9969	.9966	.9963	.9962	.9964
15	.9991	.9990	.9989	.9988	.9987	.9986	.9985	.9984	.9984	.9982	.9981	.9981	.9982
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0012	1.0012	1.0013	1.0014	1.0014	1.0015	1.0016	1.0017	1.0018	1.0018	1.0019	1.0020	1.0019
30	1.0026	1.0026	1.0027	1.0029	1.0030	1.0032	1.0033	1.0035	1.0036	1.0038	1.0039	1.0040	1.0038
35	1.0042	1.0043	1.0044	1.0046	1.0048	1.0050	1.0052	1.0054	1.0056	1.0058	1.0060	1.0061	1.0058
40	1.0060	1.0061	1.0063	1.0065	1.0068	1.0070	1.0072	1.0074	1.0076	1.0079	1.0081	1.0082	1.0078
45	1.0080	1.0081	1.0084	1.0086	1.0089	1.0091	1.0094	1.0096	1.0098	1.0100	0.0102	1.0103	1.0099
50	1.0102	1.0104	1.0106	1.0109	1.0112	1.0115	1.0117	1.0119	1.0120	1.0123	1.0125	1.0125	1.0121
55	1.0126	1.0128	1.0131	1.0134	1.0137	1.0139	1.0141	1.0143	1.0144	1.0147	1.0148	1.0148	1.0143
60	1.0152	1.0155	1.0158	1.0161	1.0163	1.0165	1.0167	1.0168	1.0169	1.0171	1.0172	1.0171	1.0166
65	1.0179	1.0184	1.0186	1.0189	1.0191	1.0194	1.0196	1.0196	1.0200	1.099	1.0198	1.0189	1.0190
70	1.0209	1.0213	1.0215	1.0218	1.0218	1.0221	1.0223	1.0224	1.0227	1.0225	1.0223	1.0215	1.0214
75	1.0241	1.0243	1.0244	1.0247	1.0248	1.0250	1.0251	1.0252	1.0254	1.0252	1.0250	1.0241	1.0238
80	1.0274	1.0273	1.0275	1.0277	1.0279	1.0280	1.0281	1.0281	1.0283	1.0280	1.0277	1.0268	1.0263
85	1.0308	1.0307	1.0309	1.0309	1.0312	1.0312	1.0312	1.0312	1.0312	1.0310	1.0305	1.0294	1.0289
90	1.0342	1.0342	1.0344	1.0344	1.0347	1.0346	1.0345	1.0344	1.0343	1.0340	1.0334	1.0322	1.0316
95	1.0376	1.0379	1.0380	1.0380	1.0382	1.0381	1.0379	1.0377	1.0375	1.0371	1.0363	1.0351	1.0343
100	1.0411	1.0417	1.0418	1.0417	1.0417	1.0415	1.0413	1.0412	1.0419	1.0403	1.0393	1.0380	1.0370

[a] Factors for concentrations from 0 to 70% at temperatures from 0 to 60° C computed from Plato's density tables [*Kaiserlichen Normal-Eichungs Kommission, Wiss. Abh.* 2(1900)], remaining factors computed from Th. Gerlach, *Z. Ver. Deut. Zuckerind.*, 13, 320 (1863).

TABLE XXI

Increase in Volume When Sucrose is Dissolved in Water at 20 C
(g/100 ml)

Grams of Sucrose in 100 ml of Water	Resultant Solution			Grams of Sucrose in 100 ml of Water	Resultant Solution		
	Sucrose by Weight (Brix)	Specific Gravity 20/4 c	Increase in Volume (ml)		Sucrose by Weight (Brix)	Specific Gravity 20/4 C	Increase in Volume (ml)
1	2	3	4	1	2	3	4
5	4.7699	1.01694	3.073	90	47.4125	1.21546	56.174
10	9.1055	1.03446	6.165	100	50.0442	1.22981	62.483
15	13.0635	1.05093	9.259	110	52.4250	1.24301	68.802
20	16.6912	1.06645	12.357	120	54.5893	1.25520	75.130
25	20.0283	1.08109	15.461				
				130	56.5652	1.26649	81.465
30	23.1083	1.09491	18.570	140	58.3763	1.27696	87.808
35	25.9599	1.10799	21.683	150	60.0424	1.28671	94.157
40	28.6075	1.12037	24.801	160	61.5803	1.29579	100.513
45	31.0723	1.13212	27.922	170	63.0042	1.30429	106.873
50	33.3726	1.14327	31.048				
				180	64.3263	1.31225	113.239
55	35.5243	1.15387	34.177	190	65.5572	1.31972	119.609
60	37.5414	1.16396	37.310	200	66.7059	1.32675	125.984
65	39.4361	1.17356	40.447	210	67.7805	1.33337	132.362
70	41.2193	1.18273	43.587	220	68.7880	1.33961	138.744
75	42.9004	1.19147	46.729				
				230	69.7343	1.34551	145.129
80	44.4881	1.19983	49.874	240	70.6249	1.35110	151.517

(*Example* 100 ml of water at 20 C is taken and 130 grams of sucrose is dissolved therein. The resultant solution at 20 C has increased in volume 81.465 ml (column 4), the total volume being 100 + 81.465 = 181.465 ml.)

TABLE XXII

Solubility of Sucrose in Aqueous Alcohol

Otto Schrefeld Solubilities at 14 C [*Zeit. Rübenzuckerind*, **44**, 970 (1894)]			Louis Reber Solubilities at 25 C [*J. Am. Pharm. Assoc.*, p. 192 (1953)]						
					Solubility of Grams of Sucrose in				
Alcohol by Wt	Sucrose (%)	Sucrose Grams in 100 Grams of the Mixture of Alcohol and Water Solution	Alcohol in Solvent (wt%)	Alcohol in Solvent (vol %)	100 g of Solution	100 ml of Solution	100 g of Solvent	100 ml of Solvent	Density of Saturated Solution (g/ml)
0	66.20	195.8	0.00	0.00	67.6	89.7	208.6	207.7	1.3274
5[a]	64.25	179.7	8.62	9.48	65.2	85.1	187.4	184.2	1.3054
10[a]	62.20	164.5	15.79	19.42	62.2	79.5	164.8	160.0	1.2775
15	60.40	152.5	24.88	30.24	58.1	72.0	138.4	132.6	1.2411
20[a]	58.55	141.2	33.53	40.18	52.9	63.3	112.2	105.9	1.1976
25	56.20	128.3	42.48	49.99	46.1	52.8	85.7	79.3	1.1443
30	54.05	117.8	51.83	59.67	39.6	43.4	65.6	59.4	1.0949
35	51.25	105.3	61.30	68.93	25.4	25.3	33.3	30.0	0.9948
40	47.75	91.3	72.38	79.00	11.39	10.32	12.85	11.01	0.9060
45	43.40	76.6	86.15	90.36	1.675	1.391	1.703	1.401	0.8307
50	38.55	62.7	92.50	95.05	0.401	0.324	0.403	0.325	0.8070
55	32.80	48.8	99.42	99.65	0.065	0.051	0.065	0.051	0.7865
60	26.70	36.4							
65	19.50	24.2							
70	12.25	13.9							
75	7.20	7.7							
80	4.05	4.2							
85	2.10	2.1							
90	0.95	0.09							
95	0.15	0.01							
Absolute	0.00	0.00							

[a] Calculated.

TABLE XXIII

Solubility of Pure Sucrose in Water Calculated for Unit Increments of Temperature from the Equation

$S = 64.397 + 0.07251\ t + 0.0020569t^2 - 9.035 \times 10^{-6}\ t^3$

(D.F. Charles, *ISJ*, pp. 126–31, 1960)

t, Temp. C	*S*, % Sucrose by Weight (in air)	Sucrose per 100 of Water	*t*, Temp. (C)	*S*, % Sucrose by Weight (in air)	Sucrose per 100 of Water	*t*, Temp. (C)	*S*, % Sucrose by Weight (in air)	Sucrose per 100 of Water
0	64.40	180.9	30	68.18	214.3	60	74.20	287.6
1	64.47	181.5	31	68.35	216.0	61	74.42	291.0
2	64.55	182.1	32	68.53	217.7	62	74.65	294.4
3	64.63	182.7	33	68.70	219.5	63	74.87	297.9
4	64.72	183.4	34	68.88	221.4	64	75.09	301.5
5	64.81	184.2	35	69.07	223.3	65	75.32	305.2
6	64.90	184.9	36	69.25	225.2	66	75.54	308.9
7	65.00	185.7	37	69.44	227.2	67	75.77	312.7
8	65.10	186.6	38	69.63	229.2	68	76.00	316.6
9	65.21	187.5	39	69.82	231.3	69	76.22	320.6
10	65.32	188.4	40	70.01	233.4	70	76.45	324.7
11	65.43	189.3	41	70.20	235.6	71	76.68	328.8
12	65.55	190.3	42	70.40	237.8	72	76.91	333.1
13	65.67	191.3	43	70.60	240.1	73	77.14	337.4
14	65.79	192.3	44	70.80	242.5	74	77.36	341.8
15	65.92	193.4	45	71.00	244.8	75	77.59	346.3
16	66.05	194.5	46	71.20	247.3	76	77.82	350.9
17	66.18	195.7	47	71.41	249.8	77	78.05	355.6
18	66.32	196.9	48	71.62	252.3	78	78.28	360.4
19	66.45	198.1	49	71.83	254.9	79	78.51	365.3
20	66.60	199.4	50	72.04	257.6	80	78.74	370.3
21	66.74	200.7	51	72.25	260.3	81	78.96	375.4
22	66.89	202.0	52	72.46	263.1	82	79.19	380.6
23	67.04	203.4	53	72.67	265.9	83	79.42	385.9
24	67.20	204.8	54	72.89	268.8	84	79.65	391.3
25	67.35	206.3	55	73.10	271.8	85	79.87	396.8
26	67.51	207.8	56	73.32	274.8	86	80.10	402.5
27	67.68	209.4	57	73.54	277.9	87	80.32	408.3
28	67.84	211.0	58	73.76	281.1	88	80.55	414.1
29	68.01	212.6	59	73.98	284.3	89	80.77	420.1
						90	81.00	426.2

TABLE XXIV

Boiling Point Elevation (or Rise) for Cane Products
(at 760 mm pressure)
(Courtesy Hawaiian Sugar Technologists

Total Solids	Purity of Syrup of Massecuite							
	100	90	80	70	65	50	45	35
	Elevation in Boiling Point (C)							
92	20.5	22	23	24	25	26	27	29
90	19	20	21	22.5	23	24.5	26	27
85	13	14	14.5	15.5	16.5	17.5	18.5	19.5
80	9	10	10.5	11	12	12.5	13.5	14
75	6.5	7	7.5	8	9	9.5	10	10.5
70	5	5.5	6	6.5	7	7.5	8	8
65	4	4	4.5	5	5.5	5.5	6	6.5
60	3	3	3.5	4	4	4.5	5	5
55	2	2.5	3	3	3	3.5	4	4
50	2	2	2	2.5	2.5	3	3	3.5
40	1	1	1.5	1.5	2	2	2	2.5
30	0.5	1	1	1	1	1	1.5	1.5

TABLE XXIV (A)

Boiling Point of Water under Vacuum

Vacuum		Temperature		Vacuum		Temperature	
In. Hg	mm Hg	C	F	In. Hg	mm Hg	C	F
23.62	600	61.5	142.7	25.79	655	52.6	126.7
23.82	605	60.8	141.4	25.98	660	51.6	124.9
24.02	610	60.1	140.2	26.18	665	50.5	122.9
24.21	615	59.3	138.7	26.38	670	49.5	121.1
24.41	620	58.6	137.5	26.58	675	48.3	118.9
24.61	625	57.8	136.1	26.77	680	47.1	116.8
24.80	630	57.0	134.6	26.97	685	45.8	114.5
25.00	635	56.2	133.2	27.17	690	44.5	112.1
25.20	640	55.3	131.5	27.36	695	43.1	109.6
25.39	645	54.5	130.1	27.56	700	41.5	106.7
25.59	650	53.5	128.3				

TABLE XXV

Specific Gravity and Brix of Milk of Lime at 27.5°C
(According to D'Ans and Lax)*

Apparent Specific Gravity	Brix	Apparent Specific Gravity	Brix
1.0049	1.3	1.0788	19.2
1.0132	3.4	1.0861	20.8
1.0205	5.2	1.0934	22.4
1.0278	7.0	1.1006	24.0
1.0350	8.8	1.1078	25.6
1.0423	10.6	1.1151	27.2
1.0496	12.4	1.1224	28.8
1.0569	14.1	1.1297	30.3
1.0642	15.8	1.1369	31.8
1.0715	17.5	1.1442	33.3

*J. D' Ans and E, Lax, *Taschenbuch für Chemiker und Physiker*, 1949. (Values checked in laboratory by Dr. Pieter Honig, according to personal communication, 1960).

TABLE XXVI

Solubility of Lime in Sugar Solutions at 25°C [a]
(Compiled by E.E. Coll, 1961)

Sucrose, % of Solution	CaO, % of Solution	Specific Gravity % of Solution[b]	Sucrose % of Solution	CaO, % of Solution	Specific Gravity % of Solution[b]
0	0.122	1.001	18	3.54	1.118
2	0.235	1.010	20	4.18	1.133
4	0.43	1.022	22	4.86	1.149
6	0.68	1.034	24	5.57	1.162
8	1.00	1.047	26	6.32	1.174
10	1.39	1.060	28	7.06	1.184
12	1.84	1.074	30	7.83	[c]
14	2.36	1.089	32	8.63	[c]
16	2.94	1.103	34	9.45	[c]

[a] Sucrose and CaO values from Seidel (Linke), *Solubility of Inorganic Compounds*, 4th Ed., N.Y., 1958.

[b] Specific gravity values from data of Table 15, *Cane Sugar Handbook*, 8th Ed., N.Y., 1945.

[c] Forms sucrate.

TABLE XXVII

Solubility of Certain Salts in Water in the Presence of Sucrose
(Jacobsthal, *Zeit, Rübenzuckerind,* **18,** 649; taken from Sidersky's
Traitè d'analyse des matières sucrèes, p. 11)

Solution containing	5% Sucrose (g)	10% Sucrose (g)	15% Sucrose (g)	20% Sucrose (g)	25% Sucrose (g)
Calcium sulfate	2.095	1.946	1.593	1.539	1.333
Calcium carbonate	0.027	0.036	0.024	0.022	0.008
Calcium oxalate	0.033	0.047	0.012	0.008	0.001
Calcium phosphate	0.029	0.028	0.014	0.018	0.005
Calcium citrate	1.813	1.578	1.505	1.454	1.454
Magnesium carbonate	0.317	0.199	0.194	0.213	0.284

Note that no temperature is given for this table.

TABLE XXVIII

Solubility of Invert Sugar
(NBS — C440, 1942, p. 691)
Approximate composition of invert-sugar solutions saturated with respect to dextrose at various temperature (computed).

Temperature (C)	Dextrose in water (%)	Composition of Invert Sugar Solutions Saturated with Dextrose (%)	Invert Sugar to 100 g of water (g)
0	35.0	50.8	103.3
10.0	40.8	56.6	130.4
15.0	44.0	59.8	148.7
20.0	47.2	62.6	167.4
25.0	50.80	66.2	195.8
30.0	54.64	69.7	230.0
35.0	58.02	72.2	259.7
40.0	61.87	74.8	296.8
45.0	65.71	78.0	351.5
50.0	70.91	81.9	452.5

Note : The Solubility of invert sugar is limited by the solubility of dextrose, See also R.F. Jackson and E.J. McDonald, *J. Assoc. Offic. Agric, Chemists,* 1942, p. 675.

TABLE XXIX

Most Soluble Mixtures of Sucrose and Invert Sugar
(*NBS* — C440, 1942, p. 692)

Temperature (C)	Sucrose (%)	Invert Sugar (%)	Water (%)	Sucrose to 100 g of Water (g)	Invert Sugar to 100 g of Water (g)	Total Sugar to 100 g of Water (g)	Sucrose Alone to 100 g of Water (g)
0	43.7	27.2	29.1	150.2	93.5	243.7	179.2
10	40.9	31.8	27.3	149.8	116.5	266.3	190.5
15	39.1	34.8	26.1	149.8	133.4	283.2	197.0
23.15	36.3	39.9	23.8	152.5	167.6	319.1	208.5
30	33.6	45.4	21.0	160.0	216.2	376.2	213.6
40	31.1	50.7	18.2	170.9	278.6	449.5	238.1
50	27.7	58.0	14.3	193.7	405.6	599.3	260.4

TABLE XXX

Cellulose papers – Whatman

Qualitative		Qualitative Wet strength		Low ash		Ashless		Hardened hardened		Ashless	
Grade	IPP µm	Grade	IPP µm	Grade	IPP µm	Grade	IPP µm	Grade	IPP µm	Grade	IPP µm
90	> 30	**113**	> 30								
4	20-25	**114**	20-25	**31**	20-25	**41**	20-25	**54**	20-25	**541**	20-25
7	16					**43**	16				
91	15										
1	11	**111**	12								
2	8			**30**	8	**40**	8	**52**	7	**540**	8
29	8										
3	5										
6	3					**44**	30				
5	25	**115**	2,7	**32**	2,5	**42**	2,5	**50**	2,7	**542**	2,7

APPENDICES

APPENDICES

APPENDIX

A. Devices for continuous sampling of First Expressed Juice and Mixed Juice.

B. Preparation of Standard Solutions.

C. Specifications for and methods of standardization of Brix hydrometers, Saccharimeters and Pol tubes.

D. Method of preparation of Seed Slurry.

E. Calculation of Brix-free-cane-water % fibre. (BFCW % Fibre).

F. Indirect method of calculating cane weight.

APPENDIX A

Devices for Continuous Sampling of First Expressed Juice and Mixed Juice.

1. H.C. & S First Expressed Juice Sampler

This consists of a removable hollow brass bolt, one inch in diameter in the bottom of the sloping Juice trough. The bolt has a hole approximately 0.5 mm in diameter which permits juice to drop in a sample can below. See Fig. A-1. The juice flowing to the sampler is screened fairly well under the front roll of the first mill by its collection in a perforated pipe which is relatively self cleaning.

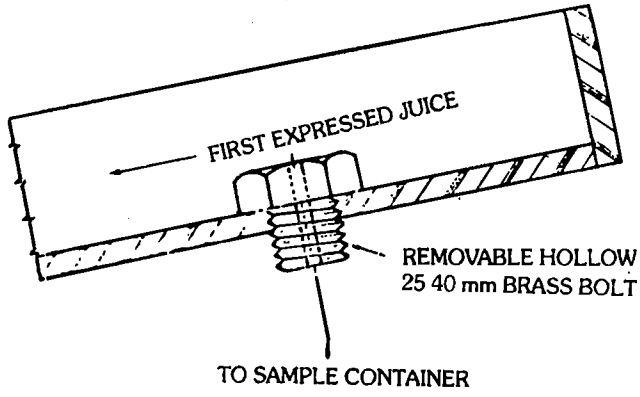


Fig. A-1 : H.C. & S. FIRST EXPRESSED JUICE SAMPLER

Devices made of copper are less susceptible to growth of micro-organisms than those made of stainless steel or plastic.

(Fig. A-1. Taken from "Factory Analytical Control, Hawaii" by J.H. Payne)

2. Webb First Expressed Juice Sampler

This sampler performs well in sampling first expressed juice. See Fig. A-2. It is a paddle wheel propelled by the Juice flow and hence gives a sample approximately proportional to flow. The half-round indentations along the blades are to prevent the juice from being thrown off the blades by centrifugal force, to allow each blades to pick up approximately the same amount of juice per revolution regardless of the speed of rotation and to carry the juice over to the center so that it will drop into the collecting flume in the saddle, thus exposing more or less collecting surface to the rotating sampler. Note that the collecting flume fits loosely in the saddle and may be lifted out and washed each time the sample container is changed.

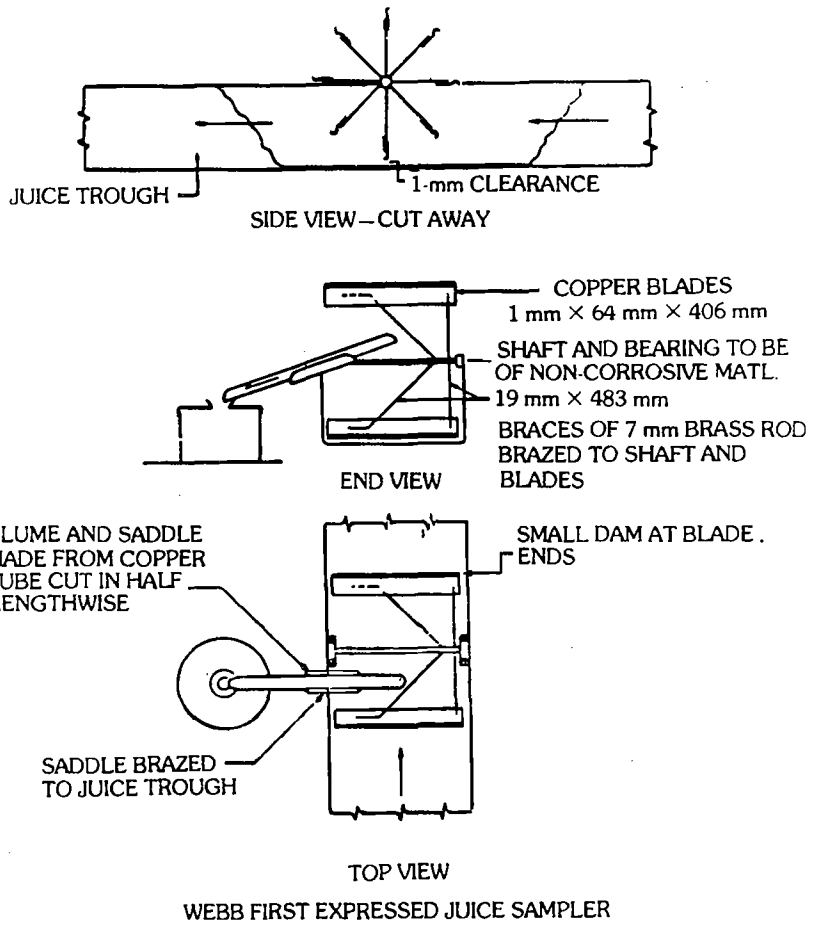


Fig. A-2

(Fig. A-2. Taken from 'Cane Sugar Handbook' by Chen, 11th edition)

3. First Expressed Juice Sampling Device (Pakistan)

In this device a juice trough (made of copper) is placed below the first two rollers of the milling tandem so as to collect the juice from the entire length of the roller. This juice trough is covered with a sloping perforated hinged flap made from old centrifugal screen to prevent bagasse particles from falling into the trough and

choking it. A copper pipe is connected to the side of the trough, through which the juice flows out into the juice sampler. A steam connection should be provided at a suitable point to keep the sampler clean. Cleaning should not be done when the sampling is being done.

The constructional details are shown in Fig. A-3.

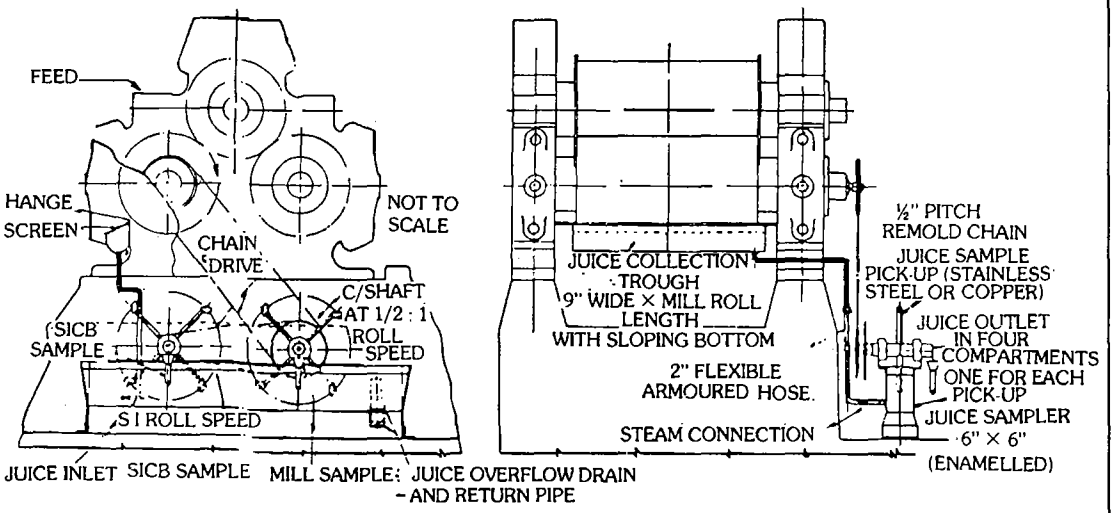


Fig. A-3 : FIRST EXPRESSED JUICE SAMPLER

(Fig. A-3. Taken from Uniform Methods of Chemical Control for Pakistan Cane Sugar Factories).

4. Wainaku Mixed Juice Sampler

This automatic, proportionate mixed juice sampler is simple and reliable. As shown in Fig. A-4 the sampler consists of a 19 mm pipe welded into the mixed juice scale tank about 230 mm down from the mixed juice level when full, and a quick-acting valve on this sample pipe that is operated by the scale tank valve operating lever. With each dump of the scale tank a small sample of mixed juice is directed into the juice container.

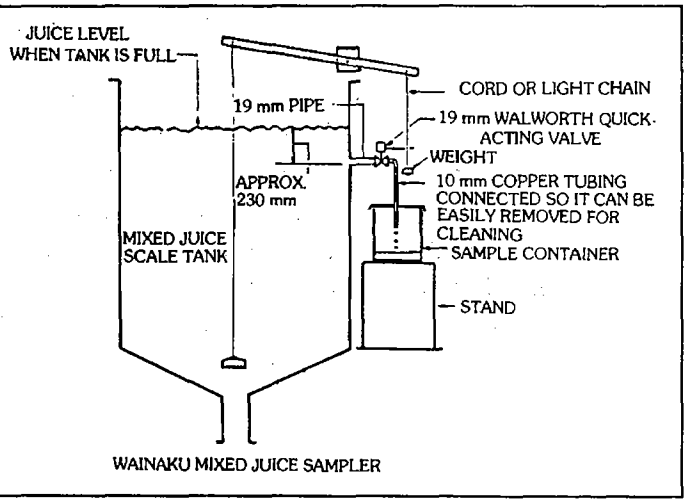


Fig. A-4

(Fig. A-4. Taken from Cane Sugar Handbook by JCP Chen)

5. Java Mixed Juice Sampler

This sampler is mechanically operated. Its scoops are made of copper. Its design is shown in Fig. A-5. The scoop is fixed in such a way that the juice can be sampled along the whole width and down to the bottom of the gutter and that the scoop can be easily removed and fixed again. For collecting each sample it is necessary to have two complete sets of scoops so as to be able to substitute every hour the one which is to be brought to the laboratory to be cleaned and disinfected.

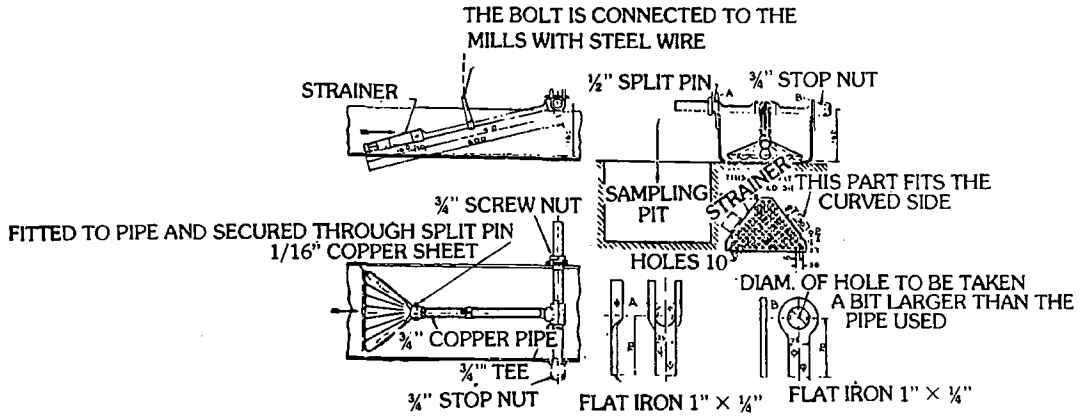

THE BOLT IS CONNECTED TO THE MILLS WITH STEEL WIRE
STRAINER
½" SPLIT PIN
¾" STOP NUT
SAMPLING PIT
STRAINER
THIS PART FITS THE CURVED SIDE
¾" SCREW NUT
FITTED TO PIPE AND SECURED THROUGH SPLIT PIN
1/16" COPPER SHEET
HOLES 10
DIAM. OF HOLE TO BE TAKEN A BIT LARGER THAN THE PIPE USED
¾" COPPER PIPE
¾" TEE
¾" STOP NUT
FLAT IRON 1" × ⅛"
FLAT IRON 1" × ⅛"

Fig. A-5 : JAVA MIXED JUICE SAMPLER

Note : Whichever sampling device is employed care should be taken to ensure that the sample obtained is representative and proportionate and is not contaminated, the device is self cleaning or clog free and not prone to mechanical failure and the evaporation or moisture absorption is minimum.

6. Mixed Juice Sampling Device

Design of a mixed juice sampling device is shown in Fig. A-6

In this arrangement a copper tube of about 25-32 mm dia is placed in such manner that its one end is in the outflow of the juice during its discharge from the scale tank. It is inserted in the stream of the juice to such a depth that sufficient juice can be collected per tip. Care should be taken to exclude excessive amount of froth which may enter the sampler at the end of the discharge. The distance between the point of sampling and the discharge into the sampling bucket should be as small as possible to avoid any evaporation or deterioration during sampling. Care should be taken that no outside matter like, washing or dripping from a leaking pipe, fall into the bucket. A sampling tube should be provided to permit cleaning which should be done in every shift.

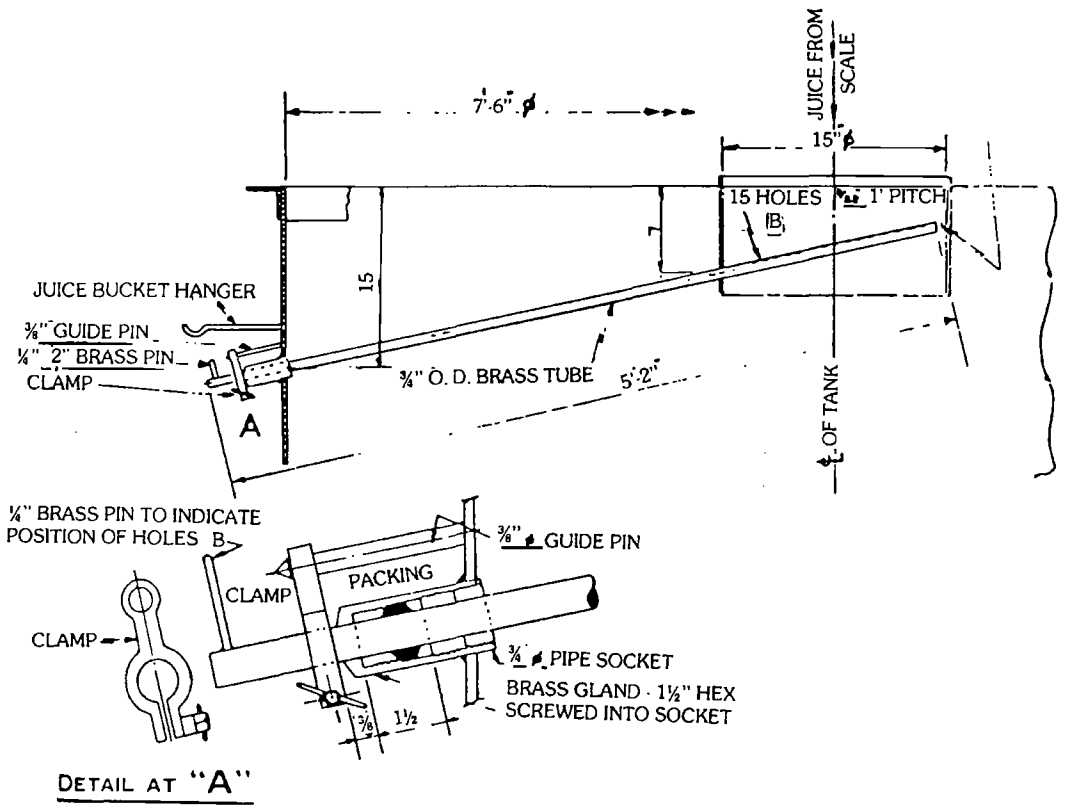


Fig. A-6 : MIXED JUICE SAMPLER

(Fig. A-6. Taken from UMCC for Pakistan Cane Sugar Factories, 1977 edn.).

APPENDIX B

Preparation of Standard Solutions*

Standard solution used in quantitative volumetric analyses are usually prepared on the basis of normality. A normal solution is one which contains one gram equivalent weight of the active reagent in one litre of the solution.

The methods of preparation of standard solutions often used, are given below:

(i) 0.1 N, Sulphuric Acid (H_2SO_4):

Preparation:

First prepare 1.0 N H_2SO_4 as follows. Fill 1000 ml volumetric flask about half full with distilled water and add from a burette 29 ml of sulphuric acid (1.84 SpGr). Mix with a rotary motion and cool to room temperature. Complete to volume with distilled water.

Standardisation:

Weigh on an analytical balance 1.0599 g of previously dried sodium carbonate (special anhydrous). Transfer to a 300 ml Erlenmeyer flask and add approx. 100 ml of distilled water. Mix until the crystals are dissolved. Add 2 drops of methyl orange solution and titrate with the prepared acid to a point where colour changes from yellow to orange. This titration should require exactly 20 ml of N.H_2SO_4. Adjust to exact normality or determine normality factor.

The 0.1 N H_2SO_4 is prepared by pipetting 100 ml of 1.0 N H_2SO_4 into 1000 ml vol. Flask and making upto mark with distilled water.

Adjustment of normality or determination of normality factor

Example : Adjustment of 0.05 N Silver nitrate solution.

The titration of 0.05 $AgNO_3$ solution against 25 ml of 0.05 N solution of sodium chloride should be 25.0 ml. Suppose it required only 24.6 ml of $AgNO_3$ solution, which would indicate that the solution is too concentrated and must be diluted.

Then, $\frac{25}{24.6} = 1.016$ is the normally factor or 1000 ml should be diluted to 1000 x 1.016 = 1016 ml or 1016 – 1000 = 16 ml distilled water should be added to 1000 ml of the solution.

Instead of adjusting the normality of the solution, the correct amount of the solution of 0.05 N which would be used in titration is obtained by multiplying the actual amount used in titration by the normality factor, in this case 1.016.

(ii) **0.1 N, Hydrochloric Acid (HCl)**

Preparation

Transfer 8.45 ml of chemically pure conc. Hydrochloric acid of 1.18-1.19 Sp. Gr. From a burette to 1000 ml vol. Flask about half full with distilled water. Mix thoroughly, cool and make to volume with distilled water. Store in a glass stoppered bottle.

Standardisation

Weigh in an analytical balance 2.6501 g of previously dried sodium carbonate and transfer to 500 ml vol flask. Fill approx. half full with distilled water and shake until the salt is completely dissolved. Complete to volume and mix well. Transfer 25 ml into an Erlenmeyer flask of 300 ml capacity. Add 50-75 ml distilled water, two drops of methyl orange and titrate with the acid in the burette to end point. It should require exactly 25 ml of 0.1 N acid. If it does not, adjust to normality.

(iii) **0.1 N, Sodium hydroxide**

Preparation

Weigh exactly 4.3 g of sodium hydroxide pellets as quickly as possible, in a counterbalanced beaker on an analytical balance. Transfer to 1000 ml vol. Flask and fill half with distilled water. Mix until dissolved, cool and make to volume with distilled water. Mix thoroughly and store in a polyethylene bottle.

Standardisation

Pipette 25 ml of NaOH solution into a 200 ml Erlenmeyer flask, add 100 ml of distilled water and 5 drops of phenolphthalein solution and titrate with 0.1 N.H_2SO_4 to a faint permanent pink colour. It should require exactly 25 ml of 0.1 N acid. If necessary adjust to normality.

(iv) **0.1 N, Potassium permanganate ($KMnO_4$)**

Preparation

Weigh 3.30 g of potassium permanganate on an analytical balance. Transfer to a 500 ml Erlenmeyer flask and add about 200 ml of distilled water. Mix until the crystals are dissolved. Cover the flask loosely and allow the solution to stand for 2 or 3 days. Filter through glass wool into a 1000 ml vol. Flask and complete to volume with distilled water. Store in a glass stoppered amber coloured bottle. Shake well before use.

Standardisation

Weigh, 0.2010 g of sodium oxalate (special powder) for standardising and transfer to a 300 ml Erlenmeyer flask. Add 150 ml of hot distilled water and stir until the crystals are dissolved, then add 15 ml of 1:1 sulphuric acid. Heat to 95-100°C and titrate with a potassium permanganate until the first pink colour occurs.

The titration should require 30.0 ml of 0.1 N $KMnO_4$. Adjust normality if necessary.

(v) **0.1 N, Sodium thiosulphate ($Na_2S_2O_35H_2O$)**

Preparation:

Weigh 24.82 g of sodium thiosulphate and transfer to a 1000 ml vol. Flask. Add about 500 ml distilled water and mix well until the crystals are dissolved. Complete to volume with distilled water and mix.

Standardisation

Pipette 25.0 ml of 0.1 N potassium dichromate solution into a 250 ml Erlenmeyer flask, add about 25 ml of distilled water, 2 g of potassium iodide crystals and 7 ml of hydrochloric acid. Titrate with 0.1 N sodium thiosulphate solution until the yellow colour fades out. Add 1.0 ml of starch indicator and continue to titrate drop by drop until the blue colour changes to sea-green. This titration should require 25 ml of 0.1 N, $Na_2S_2O_3$. Adjust to normality. This thiosulphate breaks down gradually and so a new normality factor should be determined by titrating against 0.1 N, $K_2Cr_2O_7$ periodically.

Preparation of 0.1 N, $K_2Cr_2O_7$

Weigh 4.9035 g of $K_2Cr_2O_7$ crystals and transfer to a 1000 ml vol. Flask containing 500 ml of freshly boiled and cooled distilled water. Mix until all crystals dissolve. Complete to volume with above distilled water and mix. Store in glass stoppered amber coloured bottle. Shake well each time before use.

(vi) 0.05 N, Silver Nitrate ($AgNO_3$)

Preparation

Dry about 9.0 g of silver nitrate on a watch glass at 100°C for 15 mins. Transfer to a desiccator and allow to cool for 15 mins. Weigh 8.500 g on a counter balanced watch glass and transfer to 1000 ml vol. Flask. Add about 500 ml of

distilled water and dissolve the crystals. Complete to volume with distilled water and mix, store in glass stoppered amber coloured bottle.

However it may be standardized against 0.05 N, sodium chloride solution as follows:

Preparation of 0.05 N, NaCl

Dry approx. 3 g of sodium chloride crystals on a watch glass in an oven at 100°C for 30 mins. Place in a desiccator and cool. Weigh 2.922 g on an analytical balance. Transfer to 1000 ml. vol. Flask containing approx. 500 ml of distilled water and mix until dissolved. Complete to volume and mix. Store in glass stoppered bottle.

Standardisation of $AgNO_3$

Pipette 25 ml of 0.05 N sodium chloride solution into a 200 ml porcelein casserole. Add approx. 75 ml of distilled water and 1.0 ml of potassium chromate solution. Titrate with the silver nitrate while constently stirring until a faint but permanent reddish colouration is noticed. The titration should require 25 ml of 0.05 N silver nitrate. Adjust the normality.

Preparation of potassium chromate (K_2CrO_4)

Dissolve 5.0 g of K_2CrO_4 in approx. 75 ml of distilled water in a 200 ml beaker. Add $AgNo_3$ (0.05 N) solution until a permanent red precipitate appears. Cover the beaker and let it stand for 12 hours or overnight. Filter into a 100 ml vol. Flask and complete to volume with distilled water.

APPENDIX C

Specifications and methods of standardization of hydrometers, saccharimeters and pol tubes:

In addition to the usual weighing and measuring instruments and apparatus, it is necessary in a sugar laboratory to calibrate in particular, the brix hydrometers, the pol tubes and the saccharimeter used in analytical work. The specifications and methods of standardization of these three items are given below:

1. **Brix hydrometer:**

1.1 *Specification of the spindle:*

The Brix or Balling hydrometers should be of the following specification:

(i) The tube bulb and stem should be made of transparent glass free from strain and visible defects.

(ii) The loading material should be fixed in the bottom part of the hydrometer. There should be no lose material elsewhere in the spindle.

(iii) The form should be such that the outer surface is symmetrical about the main axis. The tapered design shown in the side figure is preferred but any design which does not permit air bubbles to be trapped is acceptable. The hydrometer should float with its axis essentially vertical.

(iv) The strip on which the scale and inscriptions are marked should remain securely fastened and there should never be any displacement of the scale. The graduation lines should be clearly marked and should be of uniform thickness not exceeding 0.2 mm. There should be no irregularity in the spacing of the graduation lines and should be at right angles to the axis of the hydrometer.

(v) The scale shall indicate grams of sucrose/100 g aqueous solution.

(vi) The standard reference temperature is 20°C but where ambient temperature is considerably higher than 20°C, the reference temperature is 27.5°C.

1.2 **Testing:**

All hydrometers for laboratory control work require testing before being put to use.

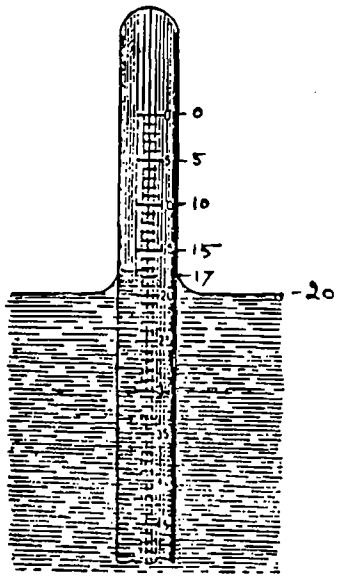
Testing may be done by preparing test solutions of different densities corresponding to the range of brix scale of the hydrometer and then checking the hydrometer readings against the test solutions. These test solutions should be made with pure sucrose on which percentage of sugar has been determined by the polariscope or by a high precision refractometer or by weighing the required amount of pure sugar and making to volume in a volumetric flask. High purity refined sugar such as cube sugar may be used in place of pure sucrose. The spindle should be tested at or near the reference temperature of 20°C or 27.5°C in an air-conditioned or constant temperature room. If the test is made at ambient temperature, the reading corrected to temperature will indicate the accuracy of the hydrometer.

1.2.1 *Method of taking the reading:*

The spindle should be lowered into a tall narrow cylinder (Winter's cylinder shown in figure) employed for holding the liquid under test in such a way that the surface of the stem above the liquid is not moistened. The best method is to sink the hydrometer very slightly below the point where it floats naturally and then release it. Care should also be exercised that the floats freely and does not touch the bottom or the walls of the cylinder.

The reading is made by bringing the eye upto a level with the surface of the solution and noting where the border line intersects the scale; the film of liquid drawn up around the stem by capillarity should be disregarded.

The reading for the spindle for example in the figure A-7 is 20 and not 17.



FLOATING BRIX SPINDLE

Fig. A-7

Hydrometer cylinders (Winter's cylinder) either with or without lip. Should measure 40-50 mm x 300-375 mm with hexagonal base to prevent rolling. The cylinder should be filled upto the brim. The circular trough in the Winter Cylinder catches the overflown liquid when the spindle is lowered into it.

Alternatively the testing may be done against a standardised certified hydrometer. (Long stem, narrow diameter, so called Java spindle manufactured by M/s A.H. Korthof, Amsterdam, Holland, with certificate, may be used).

A glass cylinder which is big enough to hold the standardised hydrometer as well as the hydrometer to be tested, should be filled with a set of solutions and the readings in both the hydrometers taken and compared. Atleast three comparisons are made, two at each end of the scale of the hydrometer and one approximately in the middle. The method, of taking the readings should be as described above under 1.2.1. Differences found in the spindle under test should be noted.

2. Saccharimeter or Polariscope:

These are of three types – (i) circular polarimeters, (ii) quartz wedge saccharimeters equipped with either monochromatic light source (540-590 nm) or with incandescent lamp with effective wavelength 587 nm isolated by a suitable filter and (iii) saccharimeters with compensation by Faraday cells and monochromatic light source (between 540 and 590 nm). Quartz wedge compensation saccharimeters with incandescent lamp are generally in use in sugar factories in India.

For standardisation, the zero point of the polariscope scale should be checked using 200 mm standard pol tube filled with distilled water. If there is any difference it should be adjusted with the help of the micrometer screw provided for the purpose.

Saccharimeter reading shall then be standardised by means of certified quartz plates or plates which have been compared with standard quartz plates. Five standard plates covering a range of 25^0 to 100^0S should be used. Readings of the saccharimeter are taken in exactly the same manner as with pol tubes filled with a sugar solution. Average of five readings should be taken with each plate.

The error at any point of the scale must not exceed $\pm$ 0.1 scale degree. A scale correction based on quartz plate readings shall be applied to all polarisation readings.

3. Pol Tubes and cover glasses:

3.1 *Specification:*

Pol tubes must be suitable for the instrument in which they are to be used.

The material of construction must be such as to obviate any change in its length which may be brought about by chance deformation. It should withstand cleaning fluids of both high and low pH, including 50% acetic acid.

The tube and its supports shall be such that the axis of the tube is aligned with the axis of the light path within 0.5 degree of arc. The axis is usually 15 $\pm$ 0.1 mm above the bottom of the trough. If a glass tube with threaded metal collar is used the collars shall be fitted such that they do not project beyond the glass ends of the tube and the ends of the tube shall not project more than 1 mm beyond the collars.

The clear aperture of the tube shall not be more than 10 mm not less than 7 mm.

The ends of the tube shall be square to their axes flat and parallel within close limits.

Tolerance in length:

The measured lengths of the tube shall not depart, at 20°C from its nominal length by more than the amount shown below:

Nominal length (mm)	10	20	50	100	200	400
Class A (μm)	± 1	± 2	± 5	± 10	± 20	± 40
Class B (μm)	± 20	± 40	± 100	± 200	± 400	± 800

The tube shall bear a mark as to whether it is of class A or class B.

Cover glasses must be suitable for the tubes on which they are to be used. They shall be made from clear, colourless optical glass thoroughly annealed and free from internal strain.

They shall be of 1 to 2 mm thickness with slightly rounded edges. They shall have good optical finish, flat within 0.01% of the length of the tube with which it is to be used and parallel within 5 mm of arc. They shall be sufficiently free from birefringence when the pol tube is rotated through 180° about its own axis. The variation in polarimetric readings shall not exceed 0.01°S.

3.2 *Standardisation:*

The actual length of the tube to be used should be checked with the help of a precision steel vernier whose jaws can accommodate the pol tube. At least five measurements must be made giving a slight rotation after each measurement. Average of the five readings should be taken as the correct length of the tube.

A cell length correction equal to nominal length divided by actual length can then be applied as a multiplier to all polarization readings.

Note: From July 1988 New International sugar scale characterized on °Z instead of °S has come into force. To convert °S in to °Z. multiply the value of °S by the factor 0.999710.

APPENDIX D

Method of Preparation of Seed Slurry

(i) *Preparation of slurry by grinding:*

600 gms of best quality sugar of uniform grain size and 3 litres of rectified spirit are to be taken in a ball mill containing 150 porcelain balls of different sizes

(80 Nos. of 20 mm dia; 30 Nos. 22 mm dia; 40 Nos. of 26 mm diameter). The ball mill is run for 32 hours continuously with 65 R.P.M. The slurry of 5μ will be ready after grinding the sugar for 32 hours. The size of the slurry grains is then measured with the help of a microscope.

(ii) *Preparing the slurry by precipitation:*

The sugar slurry is prepared by dissolving a known quantity of sugar in a specific volume of water so as to get a saturated solution at a particular temperature and pouring the above volume of sugar solution in the rectified spirit contained in a ball mill. A round ball mill having smooth inner surface is to be employed. This has a spindle held at an angle of 45^0 and may be got fabricated.

560 gms of good quality sugar is to be dissolved in 200 ml of water at 70^0C, so as to get a supersaturated solution on cooling. This hot solution free from any turbidity is slowly added in the running ball mill having 2 litres of rectified spirit with the help of a long stem funnel which is to be held dipped in the spirit so that the sugar solution may immediately be distributed in the spirit. The ball mill is run for about 30 mints. so that the sugar that comes out in the form of a precipitate grows uniformly to give a uniform size of slurry. This is to be taken out in the measuring cylinder and allowed to settle for about 10-15 mts. after which the supernatent alcoholic layer is replaced by fresh volume of alcohol.

This slurry is again run in the ball mill for another 10-15 mts. of obtain the final slurry ready for use in the pans. The size of slurry obtained by this method will be between 3 to 5μ.

In order to obtain a slurry of more regular sized crystals, 25% by volume of dispersion oil is added to the ball mill after 30 minutes of the addition of sugar solution to the alcohol.

Slurries prepared in the above manner should be used up in 36-48 hours.

Quantity of slurry to be introduced into the pan:

The number of sucrose crystals per mg for various crystal sizes (linear) are found to be as follows:

Linear crystal size	No. of crystals/mg
1 – 2 μ	± 400 – 500 x 10^6
2 – 3 μ	± 50 x 10^6
5 μ	± 6 – 7 x 10^6

The weight of sucrose crystals of 0.3 mm linear size is 0.029 mg or say 0.3 mg.

One mg of sugar of 0.3 mm size will contain 34 crystals. Based on the above the quantity of sugar in the slurry required per tonne of massecuite can be calculated from the following formula:

$$Q = \frac{C \times 10^6 \times n}{N \times 100}$$

Where Q = Quantity of sugar in slurry in grams

C = Crystal % massecuite

n = No. of crystals per mg in C massecuite

N = No. of crystals per mg of sugar in the slurry.

Thus for 5 μ size of crystals in the slurry and 40% crystal content in C massecuite the weight of sugar in slurry per tonne of massecuite will be:

$$Q = \frac{40 \times 10^6 \times 34}{7 \times 10^6 \times 100} = 1.943 \text{ say } 2 \text{ gms.}$$

For a 40 ton pan the quantity would be 80 gms. In actual practice the quantity required is several times more and may be determined by a few trials.

APPENDIX E

Calculation of Brix Free Cane Water % Fibre (BFCW % Fibre)

BFCW % fibre = Weight of Cane % fibre – dirt correction MJ % fibre - juice in cane % fibre – 100

Where, weight of cane % fibre = $\frac{100}{\text{Fibre \% Cane}} \times 100$

and Dirt correction MJ % Fibre = $\frac{\text{Dirt Corr. MJ \% Cane}}{\text{Fibre \% Cane}} \times 100$

Juice in Cane % fibre = Undil juice in MJ % fibre + Undil juice in bagasse % fibre

Undil juice in MJ % Fibre = $\frac{\text{Undil juice in MJ \% Cane}}{\text{Fibre \% Cane}}$

Undil juice in MJ % cane = $\frac{\text{Brix \% MJ} \times \text{MJ \%Cane}}{\text{Brix \% PJ}} \times 100$

$$\text{And, Undil juice in bagasse \% fibre} = \frac{10000 \times \text{Brix in last mill bagasse}}{\text{Brix \% PJ} \times \text{Fibre \% bagasse}}$$

$$\text{where, Brix last mill bagasse} = \frac{\text{Pol in bagasse} \times 100}{\text{Purity last mill juice}}$$

and Fibre % bagasse = Dry substance of bagasse – Brix bagasse.

It may be stated here that although the presence of 'brix free' or 'undetermined' or 'colloidal' water in cane and in extracted juice is generally recognized, the ISSCT recommends the concept of 'absolute juice' defined as 'cane minus dry fibre' which ignores the 'undetermined water'.

(Note: The BFCW % fibre as calculated by the above formula will vary between 10 and 30, average being around 20. Considerable variation from this figure for the same variety of cane would indicate wrong data).

APPENDIX F

Indirect Method of Calculating Cane Weight

Cane = Dirt + Undiluted juice + Undiluted bagasse. The calculation is best illustrated by an example.

Data

Wt. of Mixed juice	=	86110 Qtls.
Wt. of imb. Water	=	20055 Qtls.
Dirt	=	176 Qtls.
Brix % Primary juice	=	15.58
Brix % Mixed juice	=	13.35
Pol % bagasse	=	2.5
Purity Last expressed juice	=	62.0
Moisture % bagasse	=	48.00
∴ Dry matter % bagasse	=	52.00
Assume BFCW % fibre	=	20.0

Then,

Undiluted juice in MJ $= \frac{13.35}{15.58} \times 18110 = 73787$ Qtls.

Fibre % bagasse = Dry matter % bagasse – Brix % bagasse

$= 52 - \frac{2.5}{62} \times 100$

$= 52 - 4.03 = 47.97$

when fibre is 100, BFCW is 20 or the mixture is 120 when fibre is 47.97, the mixture will be $\frac{47.97 \times 120}{100} = 57.56$

Now Undil juice % bagasse = x 100 = 25.86

Bagasse = Fibre % bagasse + BFCW % bagasse + Undiluted juice % bagasse + Water % bagasse

The mixture (Fibre + BFCW) % bagasse = 57.56

Undiluted juice % bagasse = 25.86

or 100 bagasse = 57.56 + 25.86 + Water % bagasse

∴ Water dilute bagasse

= 100 – (57.56 + 25.86) = 16.58

Now undiluted juice in MJ = 73787 Qtls.

Imbibition water = 20055 Qtls.

Total = 93842 Qtls.

But Mixed juice is = 86110 Qtls.

∴ Water in bagasse = 7732 Qtls.

But 16.58 Qtls. of water corresponds to 100 Qtls. of dilute bagasse.

∴ 7732 Qtls. will correspond to $\frac{7732 \times 100}{16.58} = 46634.5$ Qtls. of dil bagasse

But 100 dil. Bagasse gives 100 – 16.58 = 83.42 Qtls. of undiluted bagasse.

∴ 46634.5 Qtls. of dilute bagasse will give

$$\frac{46634.5 \times 83.42}{100} = 38902.5 \text{ Undil bagasse}$$

$\therefore$ Cane weight = 176 + 73787 + 38902.5

= 112865.5 Qtls.

Note : (As the accuracy of cane weight calculated in the above manner is dependent upon the accuracy of various quantities and analytical results involved, it will provide only a very rough check of the cane weight).

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SYSTEM OF TECHNICAL CONTROL FOR CANE SUGAR FACTORIES IN INDIA